Sewage Works

PRACTICAL RESULTS OF STEP AERATION *

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Step aeration is a modification of the activated sludge process. Gould (1) has described the design of the step aeration tanks as follows: "These tanks incorporate a principle, original, it is believed, with the author, whereby the sewage can be introduced in regulated amounts at multiple points throughout the course of the flow of the returned activated sludge through the tanks." Other terms suggested by McKee and Fair (2) to describe step aeration are "distributed loading," "multiple-point dosing" or "incremental feeding."

The step aeration principle has been incorporated in the design of the Tallmans Island, Bowery Bay, Jamaica and 26th Ward plants in the city of New York. The aerators at these plants have the facilities for receiving sewage in any or all four passes, with the exception of the Tallmans Island aerator, which cannot receive sewage in the third pass.

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Figure 1 is a schematic layout for step aeration at the Bowery Bay plant in New York City. There is shown provisions for the introduction of primary effluent to all four passes of the aerator. The passes are designated by the letters A, B, C and D in the direction of the flow through the aerator.

Shapiro (1) found that the use of step aeration at Tallmans Island was advantageous compared with conventional aeration when the sludge index (Donaldson) (hereinafter referred to as S.D.I. according to *Standard Methods For The Examination Of Water And Sewage*, 1946) was decreasing, or when other manifestations of poor sludge condition were present in conventional aeration. Setter (1) reported that for aeration periods of about 3 hours on pilot plant studies, step aeration was superior to conventional aeration. McKee and Fair (2), in their laboratory experiments, demonstrated that step aeration produced good effluents and sludge indices, and resulted in a saving in aeration tank volume. Also, they found that the

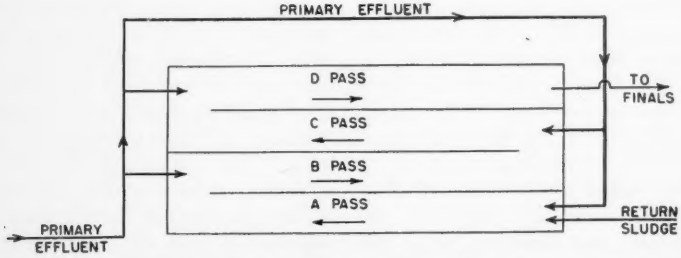

FIGURE 1.—Schematic layout of step aeration system at Bowery Bay plant, New York City.

process afforded considerable flexibility.

Gould's fundamental concepts regarding step aeration (1) were that it made possible longer solids detention in the aerator and allowed the storage of more solids under aeration for a given aerator effluent concentration than did conventional aeration. In addition, the high biological shock would be decreased by distributing the "charge," and so it was expected that oxygen utilization would be uniform throughout the length of the aerator.

In connection with the treatment of sewage solids in an aeration tank it is useful to consider the "sludge age," a term which is believed to be original with Gould. The term may be defined as the average number of days the sewage solids remain under aeration from the time they first enter the secondary system until they leave. Mathematically, the "sludge age" is calculated by dividing the weight of suspended solids under aeration by the daily suspended solids load imposed on the secondary system, the quotient to be expressed in days. Stated in another way, the "sludge age" is the reciprocal of the loading rate, expressed as pounds of suspended solids per day per pound of activated sludge solids under aeration. In the above calculation of sludge age the solids in the final tanks are not included, since they are not under aeration.

Bowery Bay Studies

In an attempt to evaluate the step aeration principle, the Bowery Bay plant was operated, using sludge age as a basic control, from March 7, 1947 to September 30, 1947. This plant employs one hour of sedimentation followed by 2.5 hours of aeration and 1.7 hours final tank detention time, based on the present flow of 40 m.g.d. and 25 per cent return sludge. The aeration tanks are the spiral flow type, 15 ft. deep, 22 ft. 3 in. wide and 275 ft. long, with two rows of diffuser plates per pass. There are 6 rectangular final settling tanks, each 94 ft. 6 in. long, 71 ft. 5 in. wide and 12 ft. 3 in. deep. Aerator effluent enters the final tanks at the bottom at one end through baffled inlets, and return sludge is removed from the far end. The longitudinal effluent weirs extend 40 ft. from the far end of the tank (3). The overflow rate of the final tanks is 1000 gal. per sq. ft. per day when all six tanks are in operation. In 1942, when secondary treatment was started, step aeration produced satisfactory results. For the duration of the war the plant was operated on modified aeration and returned to step aeration for a short period in 1946 and again in 1947.

The basic data secured from about 7 months' operation at Bowery Bay during 1947 are shown in Table I. Since two methods of feeding the aerator were employed alternately for six periods, the data have been subdivided on that basis. Figure 2 shows diagrammatically the flows, detention times and suspended solids concentrations in each of the four passes for the two methods of feeding.

During Period 1, operating by feeding equal volumes of primary effluent to B and C passes, an effort was made to maintain 70 tons of activated sludge solids under aeration to handle the 20-ton daily average primary effluent suspended solids load. In other words, the aim was to secure a 3.5-day sludge age. The load during this period varied from 15 to 25 tons per day. Likewise, it was attempted to maintain the value of the 30-minute aerator effluent cylinder settling test (cylinder) at 20 per cent or below, with particular emphasis on avoiding fluctuating cylinders throughout the day and night. Wide fluctuations in the cylinder, rising in the morning and falling thereafter, were interpreted as signifying that the final tank sludge blanket had built up on the previous day beyond the ability of the re-

TABLE I.—Step Aeration Operating Data and Results; Bowery Bay Plant, New York City

Period	No. Days	Flow (m.g.d.)	Passes Fed	Cu. Ft. Air Per Gal. Sewage	Primary Effluent (p.p.m.)		Tons SS Load	Tons SS under Aeration	Sludge Age (days)	Aerator Eff. SS (p.p.m.)	Sludge Index (S.D.I.)	Return Sludge SS (p.p.m.)	Vol. in R.S. (%)	Per Cent Return Sludge	Temp. Sewage ° Fahr.	Final Effluent (p.p.m.)		Removal in Secondary System (%)	
					SS	BOD										SS	BOD	SS	BOD
1	46	40.8	BC	0.62	124	133	21.1	69	3.3	1900	0.77	6600	76	34	60	34	20	73	85
2	53	39.0	CD	0.65	125	127	20.3	78	3.8	1560	0.68	5600	73	32	64	25	14	80	89
3	27	38.9	BC	0.68	121	124	19.6	63	3.2	1690	0.78	6200	75	31	71	13	8	89	94
4	19	38.1	CD	0.67	152	137	24.1	76	3.2	1650	0.74	5800	72	29	74	15	8	90	94
5	22	38.8	BC	0.64	99	113	16.0	59	3.7	1510	1.17	5700	75	28	74	12	9	88	92
6	41	37.1	CD	0.67	201	182	31.1	80	2.6	1660	0.81	6000	75	29	74	28	19	86	90
Weighted Ave., 1–3–5	95	39.8	BC	0.64	117	126	19.4	65	3.4	1750	0.87	6300	75	32	66	23	14	80	89
Weighted Ave., 2–4–6	113	38.2	CD	0.66	157	149	25.0	79	3.2	1610	0.74	5800	74	30	69	24	15	85	90

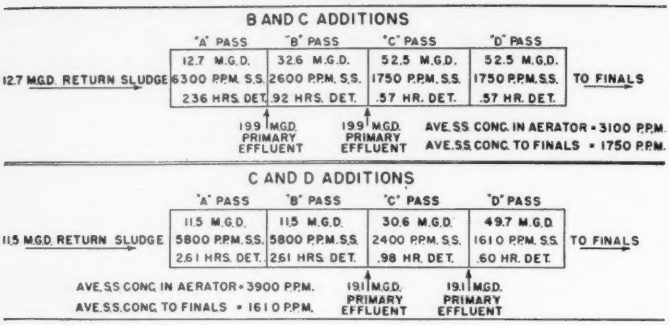

FIGURE 2.—Diagram showing average flows, suspended solids and detention periods for two methods of load application.

turn sludge rate to remove the solids. Later, actual blanket determinations confirmed this interpretation. Throughout Period 1, fair to good results were secured until near the end of the period, when the load increased. The S.D.I. dropped from 0.9 to 0.3 and the cylinders began to fluctuate widely. The daily capture of solids could not be wasted at the reduced excess sludge concentration, and the thickener blanket was out of control.

At that point, on April 21, the gate to D pass was opened, admitting primary effluent to this pass, and the gate to B pass was closed. This change marked the beginning of Period 2. Primary effluent was now being added to C and D passes rather than to B and C passes as in Period 1. The immediate effect of this change was to increase the concentration of solids in B pass to the return sludge concentration and to increase the solids in C pass from the former aerator effluent concentration to the previous concentration in B pass. There was a decrease of about 300 p.p.m. in the aerator effluent concentration, and observation showed a decreased final tank blanket. The contact time of that half of the primary effluent which was added to D pass was now about 35 minutes. The other half, which was added to C pass, received about 95 minutes of contact time. In the following four days, the S.D.I. improved from 0.3 to 0.6, and the final effluent B.O.D. dropped from about 25 to 10 p.p.m.

If, instead of changing the mode of addition of the primary effluent to cope with the high final tank blanket, the return sludge rate had been increased, as is the practice in conventional activated sludge operation, the concentration of returned sludge would have been reduced. This would have reduced the amount of solids held in the aeration tank by lowering the average concentration in the four passes, consequently lowering the sludge age. More solids would have been stored in the final tanks, which would have increased rather than decreased final tank blankets. Analysis of previous operating results had borne out these facts. In effect, the aerator had been adjusted to the return rate rather than the return rate to the aerator, by changing the method of feeding. Step aeration had made this possible by its flexibility. The step method had provided a valuable tool for restoring balance to the secondary system in an extremely short time compared with the conventional activated sludge process. A simple opening and closing of gates was all that was necessary.

As the S.D.I. improved and the cylinder decreased, the primary effluent addition was shifted within a few hours toward B pass by closing D pass

gate and opening B pass gate, while C pass remained open. When this was accomplished, the primary effluent was being fed through B and C passes, which marked the beginning of Period 3. Although plant operation did not require this change, it was considered desirable to make available the capacity for future storage of solids under aeration, in anticipation of future shock loads. It also furnished comparative data on operation under alternate feeding conditions.

The introduction of primary effluent into A pass was intentionally avoided. Mathematically it can easily be shown that even small additions to A pass appreciably lower the concentration of solids in this pass and all subsequent passes except those carrying aerator effluent concentration, thus lowering the sludge age very rapidly. If on the other hand, it were desired to carry the same suspended solids tonnage in the aerator with A pass addition as without it, considerably higher aerator effluent concentrations would be required. Experience in the summer of 1946 indicated that even small additions to A pass resulted in highly unstable operation with fluctuating indices, although good plant effluents could be obtained for periods of several weeks. The changes in mode of addition in Periods 4, 5 and 6 (Table I) were guided by the above considerations.

It must be pointed out that the overflow rate of the final tanks during Periods 4, 5 and 6 was higher than in the first three periods. The average overflow rate for Periods 1, 2 and 3 was 1030 gal. per sq. ft. per day while the rates for Periods 4, 5 and 6 were 1230, 1190 and 1130, respectively. Likewise, during Periods 4, 5 and 6 higher temporary overflow rates were caused by failure of final tank mechanisms. The average of the maximum consecutive 5-day overflow rate during Periods 1, 2 and 3 was 1200 gal. per sq. ft. per day while in Periods 4, 5 and 6 the corresponding rates were 1320, 1240 and 1400, respectively.

Although A pass or A and B passes held return sludge concentrations under aeration for the two modes of addition, yet the results were not analyzed by the conventional criteria applied to reaeration. The main consideration was the retention of amounts of activated solids under aeration sufficient to permit adequate sludge age with consequent conditioning, while providing an aerator effluent of minimum concentration of solids.

Inspection of Table I shows that C and D pass addition was superior to B and C pass addition in that it was capable of taking a larger load and turning out comparable effluents and indices. This may be explained by the fact that with C and D pass additions the sludge developed the same sludge age at higher loads and lower aerator effluent concentration. Thus, C and D pass additions averaged 79 tons of solids under aeration with an aerator effluent suspended solids concentration of 1610 p.p.m. while B and C pass additions averaged 65 tons of solids under aeration with an aerator effluent of 1750 p.p.m. Although there was a variation in the load from 16 to 31 tons of suspended solids per day, the sludge ages for the 6 periods varied less in proportion from 2.6 to 3.8 days.

Inspection of the values of the S.D.I. shows no definite trend with respect to volatile content. However, an index of 1.17 was obtained at a sludge age of 3.7 days in Period 5, while indices of 0.74 and 0.81 were reached in Periods 4 and 6 with sludge ages of 3.2 and 2.6 days, respectively. The average sewage temperature for these three periods remained constant at 74° F. In Period 2, although an average sludge age of 3.8 days was attained, the relatively lower index in this period is believed to be the result of wide variations in the sludge age during that period.

TABLE II.—Detention and Contact Times—Step Aeration Studies

Period	Sludge Detention Time (hr.)	Sewage Contact Time (hr.)	
		½ Flow	Other ½ Flow
1	4.1	2.0	1.1
2	6.3	1.5	0.6
3	4.6	2.1	1.2
4	7.1	1.6	0.6
5	4.9	2.2	1.2
6	7.3	1.6	0.6
Weighted Ave., 1–3–5	4.4	2.1	1.1
Weighted Ave., 2–4–6	6.8	1.6	0.6

Observation of the daily results at the plant showed that high loads, which depressed the sludge age, were followed by lowered indices for several days. It is believed that at higher sludge ages, the greater degree of processing under aeration which an activated sludge particle undergoes prior to leaving the secondary system, and its reduced rate of feeding, so affect its physical characteristics as to improve its settleability. The fact that this highly loaded aerator under discussion developed acceptable indices for a 7-month period is considered to be due to the greater sludge age of solids made possible by the step method of operation.

Table II shows the average detention time of the sludge solids and of each half of the primary effluent fed to the aerator for the six periods. In Periods 2, 4 and 6, half the primary effluent received about 95 minutes contact time with the sludge, and half received only 35 minutes of contact, yet this was sufficient to effect an 89 to 94 per cent removal of B.O.D. across the secondary system alone in these three periods. It is evident that the primary effluent contact time can be quite low and yet allow satisfactory treatment when step aeration is used. The sludge concentration in the 35-minute period of contact was at 1610 p.p.m. The lower limits of this time-concentration phenomenon remain to be explored. It is interesting to note that the solids detention in Periods 2, 4 and 6 averaged 6.8 hours, although if this aerator were operated conventionally the detention time would have been 2.5 hours.

Throughout the six periods, the air supply remained essentially constant, the air ratio varying from 0.62 to 0.68 cu. ft. per gal. of primary effluent. Table III shows the B.O.D. and air relationships for the six periods. The B.O.D. loadings varied from 54 to 84 lb. of B.O.D. per 1000 cu. ft. of aerator per day, with B.O.D. removals of 85 to 94 per cent by the secondary system. Greeley (4) suggests as conventional

TABLE III.—B.O.D. and Air Relationships—Step Aeration Studies

Period	Cu. Ft. Air Per Gal. Sewage	B.O.D. Load (lb./day)	B.O.D. Removed (lb./day)	B.O.D. Removed (%)	Cu. Ft. Air Per Lb. B.O.D. Removed	Lb. B.O.D. Per 1000 Cu. Ft. Aerator Per Day
1	0.62	45,200	38,400	85	660	67
2	0.65	41,300	36,700	89	690	62
3	0.68	40,200	37,600	94	700	60
4	0.67	43,500	41,000	94	620	65
5	0.64	36,500	33,600	92	740	54
6	0.67	56,300	50,400	90	490	84
Weighted Ave., 1–3–5	0.64	41,800	37,100	89	690	62
Weighted Ave., 2–4–6	0.66	47,400	42,700	90	590	71

loading with domestic sewage 25 to 30 lb. of B.O.D. per 1000 cu. ft. of aerator per day. Imhoff (5) suggests a similar rate of 31. The loadings shown in Table III range from about two to three times the average value suggested by Greeley for conventional aerators. As seen in Table III, Period 6, the oxygen was efficiently used when an average of 490 cu. ft. of air removed 1 lb. of B.O.D.

Dissolved oxygen determinations along D pass during C and D pass additions revealed an average of 0.8 p.p.m. at the beginning of the pass, remaining constant to approximately the midpoint of the pass, a detention time of about 17 minutes. At this point, there was a sharp rise in the D.O. to 2.5 p.p.m., within a 5-minute detention time. This value remained constant for another 5 minutes, and then rose sharply to 3.5 p.p.m. followed by a gradual rise to the aerator outlet. These sharp breaks indicated the satisfaction of the demand of the initial high rate oxidative process. Thus the solids in the aerator effluent were sufficiently oxidized to be sent to the final tanks. This was borne out by the satisfactory operating results.

There were very few days when this sharp D.O. rise did not occur in the aerators and, as Table IV shows, the average aerator effluent D.O. ranged from 3.5 to 5.3 p.p.m. in the six periods. However, in Period 1, with B and C pass additions, although primary effluent contact time was greater than in Periods 2, 4 and 6, the D.O. break was not present on about 1/5 of the days, and the aerator effluent averaged 1.1 p.p.m. on these days. Accompanying these low values of aerator D.O. there was a tendency toward higher B.O.D. in the final effluent. As a result of these observations, 3.5 p.p.m. of D.O. in the aerator effluent was adopted as the operating minimum in order to contain the D.O. break within the aerator, and avoid sending solids with a high oxygen demand to the final tanks.

It can be noted from Table IV that the D.O. values in the passes carrying high sludge concentrations were low by ordinary standards, yet apparently there was no deterioration of the sludge, as is evident by its activity in clarification and its oxidative capacity. It is felt that the low percentages of saturation which exist throughout most of the aerator lead to greater efficiencies of oxygen solution from the diffused air and greater rates of surface oxygen absorption. Also, for a given air ratio, this shorter detention aerator has much higher rates of air applied per square foot of aeration tank, and hence has greater surface turbulence, thereby further favoring oxygen absorption from the atmosphere.

During Period 6, the B.O.D. load applied was about 40 per cent greater than in the other periods. This increased load was satisfactorily handled with the same air supply as used previously, indicating that a significant saving in air might have been effected in the earlier periods. Worthy of mention also is the fact that the D.O. rose in the last 1/8 of the aeration tank, decreasing the oxygen absorption only in this small portion of the aerator and yet provided the high D.O. in the aerator effluent to help withstand final tank detention.

The final tanks should be considered as an integral part of the aeration

TABLE IV.—Aerator Dissolved Oxygen Data—Step Aeration Studies

Period	Passes Fed	Dissolved Oxygen (p.p.m.)				
		Beginning of A Pass	End of A Pass	End of B Pass	End of C Pass	End of D Pass
1	BC	0.5	0.5	0.6	1.1	4.0
2	CD	0.8	1.1	0.6	1.4	4.8
3	BC	0.9	0.7	0.7	2.6	5.3
4	CD	0.9	1.1	1.0	2.7	4.6
5	BC	0.9	1.0	0.7	2.3	4.8
6	CD	1.1	0.9	0.7	1.5	3.5

system. During the period under consideration the sludge returned from the final tanks varied from 28 to 34 per cent of the sewage flow. It is essential that the solids in the aerator effluent be rapidly concentrated in the final tanks so that they can be returned in this volume of returned flow.

If the sludge index is good a high concentration of solids in the aerator effluent can be physically handled. If the index is poor the solids must be reduced by dilution so that their volume after concentration is no greater than can be handled by the return sludge flow. The methods used to accomplish this have been previously discussed. It is our definite conclusion that the least possible quantity of activated solids, regardless of their settling qualities, should be passed to the final tanks, while maintaining adequate sludge age. These criteria can be attained in an aeration tank adapted to step aeration.

Summary

This paper presents the results of 7 months of operation at the Bowery Bay Sewage Treatment Works, using step aeration to treat 40 m.g.d. of sewage by the activated sludge process in 2.5-hour detention aeration tanks. Primary effluent was added to B and C passes or to C and D passes of the aeration tanks to permit reaching 3.5 days sludge age. Values of cylinders were maintained at 20 per cent or below by changing the method of feeding the aerator. Removal of 90 per cent of the B.O.D. applied to the secondary system, and development of acceptable sludge indices, were attained with B.O.D. loadings of 55 to 84 lb. of B.O.D. per 1000 cu. ft. of aerator per day and with half of the sewage flow remaining in contact with the activated sludge for 35 minutes, when C and D pass addition was used. Efficient use of the air supply is indicated, especially in Period 6, when on the average a pound of B.O.D. was removed with 490 cu. ft. of air. Change in the mode of adding primary effluent to various passes of the aerator provided for flexibility of operation in accommodating high loads.

The writer wishes to express his appreciation for the coöperation of the operating and technical personnel of the Bureau of Sewage Disposal Operation.

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CONSIDERATIONS AND PROCEDURES IN THE DESIGN OF HIGH RATE TRICKLING FILTERS *

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This paper describes the study given to operating data and the procedures in the design of a high rate trickling filter plant in routine practice by the author's firm. It includes brief descriptions of the results of operation, where a considerable amount of generally reliable data are available, and describes illustrative performance and cost trends. The application of such basic data and trends to a particular problem is included.

Definitions and Classifications

In this paper, the load on a high rate filter is expressed as the pounds of 5-day B.O.D. in the screened or settled sewage actually applied per acre-foot of filter per 24 hours, exclusive of any B.O.D. in the recirculated liquor.

The efficiency of the filter, as used in this paper, means the percentage or proportion of the load applied to the filter, removed by the filter, and by the final sedimentation tank. The terms "efficiency" and "per cent removal" are both used. Where operating data are lacking, it is assumed that final sedimentation accomplishes 15 per cent of the total reduction in B.O.D. accomplished by both the filter and the final sedimentation tank.

Low rate trickling filters, often referred to as conventional or standard rate trickling filters, in general, operate with loads of 500 to 600 lb. of applied B.O.D. per acre-ft. or less. There is, however, no definite line of division between low and high rate filters. High rate trickling filters usually operate with loads well in excess of 1,000 lb. per acre-foot. Between these approximate load limits, a filter might be designated as low or high rate, depending on local conditions. When the applied load is very high, say in excess of some 10,000 lb. per acre-ft., high rate filters are sometimes referred to as "roughing filters."

Within these general definitions, there are several kinds of high rate filter installations. The Subcommittee of the National Research Council classified high rate filters as to depth, as to the amount of recirculation, and as to the number of stages. In this report, shallow filters are considered to be those less than 4.5 ft. deep. The Handbook of Trickling Filter Design, published by *Public Works Magazine* in 1947, uses what may be considered as trade names in classifying high rate filters, such as Biofilters, Aerofilters, and Accelo Filters, with diagrams to describe each classification based largely on recirculation procedures.

In dealing with design procedures and bases of design as discussed in this paper, consideration is given to the load, to the depth, to recirculation, and to the number of stages. Using these bases, several more or less simplified and typical kinds of high rate filter plants are designated as follows:

(a) High rate trickling filters operating ahead of lower rate filters.

(b) Single stage high rate filters without recirculation.

(c) Single stage high rate filters with recirculation.

(d) High rate filters in two stages, with or without recirculation.

* Presented at the Annual Summer Conference of the Institute of Sewage Purification, Southport, England, July 6–8, 1948.

Each group or class will vary with the rate and method of recirculation and with the depth of the filter. The most desirable design is that having the lowest total annual cost for the required removal of B.O.D., with due regard to reasonably flexible operation and to local conditions.

Long-time, large-scale operating experience is not yet sufficient, in the writer's opinion, to indicate a preferred design procedure in all cases. Perhaps several procedures will be found to be useful, depending on local conditions, and facilities for flexibility in operation are indicated.

Other interesting high rate filter applications referred to in British and United States literature include enclosed aerated filters, Cyclo-Nitrifying filtration and back-wash filters.

Brief Historical Statement

Early installations of high rate trickling filters in the United States for the treatment of sewage on a full scale were in 1936, at the Camarillo State Hospital in Calif., and at Austin, Minn., in 1939. These installations were based on earlier experiments by H. N. Jenks, and by R. L. Smith and H. O. Halvorson, respectively. High rate filters were used quite extensively during World War II, when they were approved (December, 1940) by Greeley and Hansen and Metcalf & Eddy in a joint report to the War Department on sewage plants for National Defense projects, as follows:

"In many of the projects so far inspected, plants comprising high-rate trickling filters are underway and have been approved. The effluent from high-rate trickling filters may not be treated to as high a degree as the effluent from standard or low-rate trickling filters or from activated sludge. However, considering the temporary character of the projects, the desirability for economy and the possibility of the ample use of chlorination during the few years of service, the degree of treatment accomplished by high-rate trickling filters should be sufficient."

The same comment is included in the Summary and Conclusions of the Report of the Subcommittee on Sewage Treatment of the National Research Council, as follows:

"In regard to types of treatment, the Engineering Board (Greeley and Hansen and Metcalf & Eddy) preferred . . . trickling filters to activated sludge plants . . . and preferred high rate filters to standard trickling filters because of the smaller amount of material required in their construction."

This summary report tabulated 399 sewage treatment plants at army posts, of which 90 were designated as high capacity trickling filters of various kinds.

An inventory of sewage treatment plants in the United States, published by the United States Public Health Service in 1942, shows 90 municipal high rate trickling filter installations. Thus, in the United States, there are or have been in operation some 180 high rate trickling filter plants of various kinds.

Based largely on such experience, the purpose of this paper is to consider design procedures and to state, so far as seems possible, the yardsticks or bases of design which are emerging and which may serve to guide a thoughtful and prudent engineer in the development and design of the most economical and suitable sewage treatment plant for a particular set of local conditions. The problem is illustrated by the following questions:

(a) What is the safe relation between the load on and the efficiency of a high rate trickling filter?

(b) What increase in efficiency may be expected to result from recirculation?

(c) What increase in efficiency may be expected to result from series operation; that is, operation of the filters in two stages?

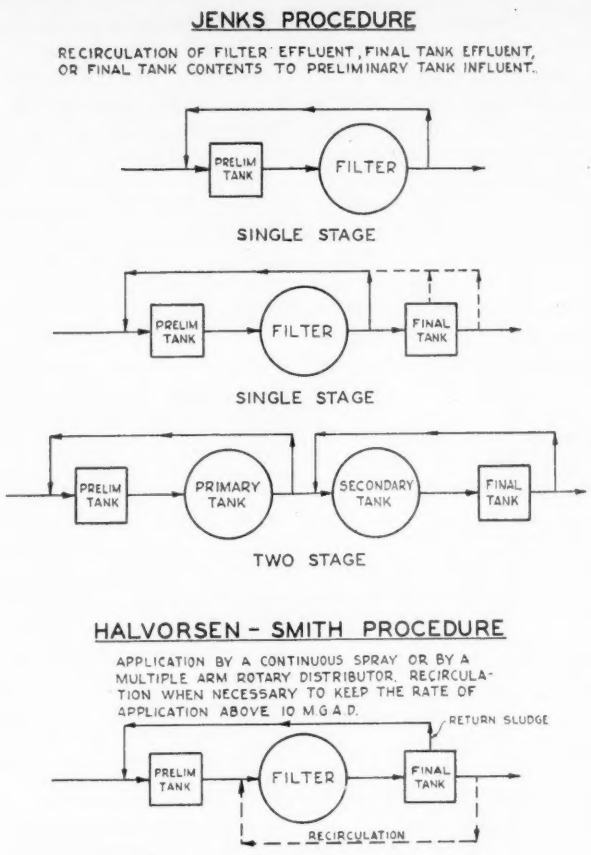

FIGURE 1.—Typical high rate filter layouts.

(d) What are the relative total annual costs of various kinds of high rate trickling filters likely to be for a particular local condition?

These and other questions must be considered and their implications understood by the engineer and his client before the design and construction of a particular project.

American Trade Types of High Rate Filters

Among the early high rate filter developments in the United States are those associated with Jenks and Halvorson and Smith, as outlined in Figure 1. Other developments were those by Ward and Shook. All have been granted patents by the U. S. Patent Office. Trade names now associated with these developments are briefly described as follows:

(a) Biofilter: "The combination of a clarifier and a trickling filter wherein filter discharge material is recycled back to the clarifier which also receives incoming feed to the system."

(b) Aero-Filter: "A process for treating sewage in a trickling filter open to atmosphere to purify the same, which comprises applying filter influent to the filter at a daily average rate of more than ten million gallons per acre per 24 hours (m.g.a.d.), and

at a distribution ratio of less than substantially ten to one." In this system it is understood that the effluent from a final sedimentation tank is recirculated to the filter if necessary to maintain a dose on the filter at a rate of some 10.0 m.g.a.d. or more.

(c) Accelo-Filter: "Accelerated biological treatment . . . by direct recirculation of large quantities of material to a rotary distributor and thence to a biological filter." Flow diagrams indicate that the effluent from the filter is recirculated directly back to the filter influent.

The brief descriptions are abstracted from the patent documents relating to the designated type of high rate filter operation.

So far as the writer knows, no patents relating to high rate filters have been reviewed by the Courts. The general principles developed by Jenks, Halvorson, Smith, and others, however, seem in the opinion of the writer to have introduced a new range of treatment into trickling filter operation. The significance of the various details in the patent documents, especially as related one to the other, is not easily discerned.

Effect of Sewage Characteristics

The effectiveness of high rate trickling filters obviously is affected in some degree by the characteristics of the sewage being treated as, for instance, the strength of the sewage, the concentration and condition of the organic matter in the sewage, the character of the organic matter as to its amenability to treatment, the temperature of the applied sewage, its age, and to other items.

Such characteristics result, in the first place, from the quantity per capita and the quality of the water supply, and, in the second place, from the quantity and kind of industrial wastes included in the sewage. Thus, some industrial wastes, perhaps those from packinghouses, may be more amenable to treatment on high rate filters than those from metal works, tanneries, or starch works. There are not sufficient operating data from which to determine the extent of the effect of these different characteristics. In this paper operating units and relationships are shown, to illustrate high rate filter loadings and efficiencies without preliminary regard to such differences. In actual design, however, the sewage characteristics, average and extreme, should be carefully determined, and the bases of design adjusted with ever-increasing exactness as information becomes available.

In the operation of two-stage filters, an important factor is the treatability of the organic matter remaining in the sewage after the first stage. It seems clear that the efficiency, as measured by the load and the quantity of organic matter removed, is lower for a second as compared to a first stage filter in two-stage operation. In the simplified computations described later, the efficiency of a second stage filter is taken as 85 per cent of the efficiency of a first stage filter.

Effect of Recirculation

It is clearly established that recirculation increases the removal of B.O.D. from the applied sewage. The questions remain as to the extent of recirculation, its method, and its overall economy. Thus, in the National Research Council report, it is stated:

> "A statistical analysis of the data for all plants indicates that recirculation in nearly any form brought about an improvement in performance that was significantly larger than the difference in performance noted between different schemes of recirculation."

Empirical formulas and illustrative computations are given in this report, which indicate that the highest exposure of organic matter to treatment results, for military establishments, in

a recirculation factor of 2.78, which means recirculating 1.78 volumes of sewage. This computation, however, is not related to the annual cost. In simplified form, both performance and cost trends are described later in this paper.

There is an interesting discussion of recirculation in a report by Jenks and Levine, published as Reprint No. 1248 from a U. S. Public Health Report dated September, 1928. This report discusses stream-flow aeration as follows:

"In natural streams, the decomposition of the sewage proceeds over a long course of flow, many miles in length, so that it was recognized that within the physical limits of a treatment plant the necessary time element, in terms of distance traversed, could not be introduced in this way. Accordingly, recirculation of the sewage over the controlled section was decided upon. . . ."

"It can be shown by computations based on the deoxygenation curve . . . that domestic sewage . . . having a B.O.D. of 350 p.p.m. should be successfully treated through six-hour stream-flow aeration of 50 times the volume of flow."

In the greatly stimulated treatment of sewage in a trickling filter, much lower recirculation ratios are found to be applicable. The most economical procedure should be provided in the bases of design.

Characteristics of Effluent

Those familiar with sewage treatment know that the characteristics of the effluent are important and complex. To what extent is it feasible and economical to produce an effluent, not only with a low content of B.O.D., but also with a high content of nitrate and nitrite nitrogen? In the simplified computations which follow, it is assumed that the effluent from high rate trickling filter plants will not accomplish any appreciable nitrification.

In the National Research Council report, it is stated that "None of the filters loaded over 1,000 pounds per acre foot produced nitrification" and further, that "It seems difficult to believe that effluents from high rate filters, dosed at rates higher than 1,000 pounds per acre foot, are just as completely treated as effluents from low rate standard filters."

In the writer's design procedure, it has not been considered to be practicable, so far, to give much weight to the extent of nitrification expected to be accomplished by high rate filters. Under local conditions where an approach to nitrification is desired, and within the range of treatment by high rate filtration, the bases of design would be selected on the conservative side of acceptable limits. The extent of the reduction of B.O.D. will vary considerably with the atmospheric temperature, being greater during warm periods of the year and in warm climates.

Operating Results

The operating results at several municipal sewage treatment plants and at one military establishment in the United States have been reviewed and summarized for this paper. The general characteristics of these installations are briefly described in the following paragraphs. As the results of operation at the military establishments have been reviewed and described in considerable detail by the Subcommittee of the National Research Council, these data are included only to a limited extent.

Austin, Minn.

This plant went into operation in 1939 and comprises the following major sewage treatment structures:

Equalizing Tank
Flocculators
Preliminary Sedimentation Tanks
Preliminary High Rate Filters
Intermediate Sedimentation Tanks
Final Standard Rate Filters
Final Sedimentation Tanks

The design of the high rate filters is based, in general, on the Halvorson-Smith procedure. The sewage treated comprises that from a human population of about 18,000, and that from a large packinghouse. The high rate filters comprising 1.0 acre-ft., have an average depth of 6 ft., with an area of 0.167 acre. The final filter, comprising 7.2 acre-ft., has an average depth of 8 ft. with an area of 0.9 acre. These filters were in existence at the time the capacity of the plant was increased by the addition of the high rate filters and other related structures. In Austin, the winters are very cold.

Springfield, Mo.

This plant has a rated capacity of 10.0 m.g.d., and went into operation in 1941. The major sewage treatment structures are as follows:

Grit Tank
Mixing Tank
Preliminary Tray Type Sedimentation Tanks
Aerated Flume
High Rate Filters
Intermediate Sedimentation Tank
Final Filters
Final Sedimentation Tanks

There are two high rate filters, each 3 ft. deep, having a total area of 0.49 acre, and comprising 1.46 acre-ft. The four final filters are 160 ft. in diameter and 5 ft. deep, thus having an area of 1.84 acres and a volume of 9.20 acre-ft. The present quantity of sewage is 4.0 to 6.0 m.g.d. To maintain a quantity dosing rate on the high rate filter, the intermediate sedimentation tank underflow is recirculated to maintain an average quantity of about 10.0 m.g.d., and a dosing rate of 20.4 m.g.a.d.

Sioux Falls, S. D.

The original plant was constructed in 1927 and was enlarged in 1937 and again between 1939 and 1942. It is designed for an average of 3.5 m.g.d. of domestic sewage and 4.2 m.g.d. of packinghouse waste.

The packinghouse waste is screened and settled at a pretreatment plant and is then pumped to the municipal plant, which has the following major sewage treatment structures:

Equalizing Tank
Grit Tank
Flocculation Tank
Preliminary Sedimentation Tanks
Aeration Tanks
Preliminary High Rate Filters
Intermediate Sedimentation Tanks
Secondary Filters
Secondary Sedimentation Tanks
Final Sedimentation Tanks

The four preliminary filters are of the back-wash type and have an area of 0.545 acre and contain 3.27 acre-ft. of stone. The final filters have an effective area of 2.8 acres and comprise 23.8 acre-ft.

Liberty, N. Y.

This plant was constructed in 1940 and has a rated capacity of 1.0 m.g.d. The population is about 4,000 in winter and 10,000 in summer. The plant comprises the following major sewage treatment structures:

Screen and Grit Chamber
Preliminary Sedimentation Tank
Preliminary Filter
Secondary Filter
Final Sedimentation Tank
Magnetite Filter

Recirculation is in effect from the primary filter effluent to the primary tank influent, and from the final tank effluent to the secondary filter influent. The filters are the same size and have a combined volume of 0.69 acre-ft., with an area of 0.23 acre.

During the summer months, the resort population considerably increases the load on the treatment plant.

Lubbock, Texas

This plant was completed in June, 1941. It was designed for a maximum flow of 5.0 m.g.d., and an average flow of 4.0 m.g.d. The recirculated liquor and the final effluent are pumped. The major sewage treatment structures are as follows:

Screen and Grit Chamber
Preliminary Sedimentation Tanks
Trickling Filters
Final Sedimentation Tanks

The filters are equipped with motor-driven rotary disk distributors that apply the sewage in a continuous spray. Recirculation is used during low raw sewage flows, generally at night. Lubbock is located in a warm and dry section of the United States.

Fort Jackson, S. C.

The original plant, constructed during World War I, was modernized and expanded in 1941, 1942, and 1943. The rated capacity of the enlarged plant is 5.0 m.g.d. It is a single stage plant with recirculation. The major sewage treatment structures are as follows:

Screens
Grit Chambers
Preliminary Sedimentation Tanks
Filters
Final Sedimentation Tanks

The four filters are 5.0 ft. in depth with a total area of 0.407 acre, and comprising 2.04 acre-ft. The plant treated the sewage from an Army camp that had an average population of about 47,000.

Mason, Mich.

The first units of this plant were constructed in 1921, and since that time modernization and enlargement have been carried out. The rated capacity is 0.35 m.g.d., a relatively small quantity. Final effluent is, in general, recirculated to the filter influent. The plant now comprises the following major sewage treatment structures:

Bar Screen and Grit Chamber
Preliminary Sedimentation Tanks
Filters
Final Sedimentation Tanks

The filter media consists of blast furnace slag 8 ft. in depth. The combined filter area is 0.0325 acre, and the volume is 0.26 acre-ft. This plant is located in a cold climate and in addition to domestic sewage, treats wastes from a plant processing milk and manufacturing pharmaceutical products.

Cedar Rapids, Iowa

This plant treats waste from a packinghouse and the domestic sewage from a city with a population of about 70,000. The major sewage treatment structures are as follows:

Revolving Screen
Equalizing Tank
Grease Remover
Flocculation Tank
Preliminary Sedimentation Tanks
Filters
Final Sedimentation Tanks

The filters comprising 26.0 acre-ft., have an average depth of 6.5 ft., with an area of 4.0 acres. There is no recirculation.

The average monthly loads and efficiencies for the foregoing sewage treatment plants are shown on Figures 2 to 6, inclusive, and are summarized in Tables I and II. Table I shows the average applied load and the efficiency. The data for Springfield, Mo., are for only six months, those for Lubbock, Texas, for eight months, and for Liberty, N. Y., for five summer months. Table II shows the pounds of applied B.O.D. per acre-foot per 24 hours per month for each plant, and the annual average per cent efficiency. Table III shows the quantity of raw sewage and the B.O.D. in parts per million in the raw sewage, in the settled sewage as applied to the filter, and

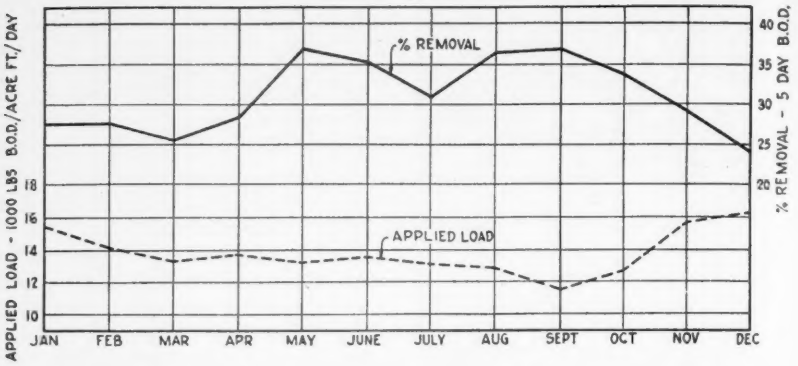
% REMOVAL
APPLIED LOAD
APPLIED LOAD - 1000 LBS B.O.D./ACRE FT./DAY
% REMOVAL - 5 DAY B.O.D.
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC

FIGURE 2.—High rate filter operating results at Austin, Minn.; 1940–47.

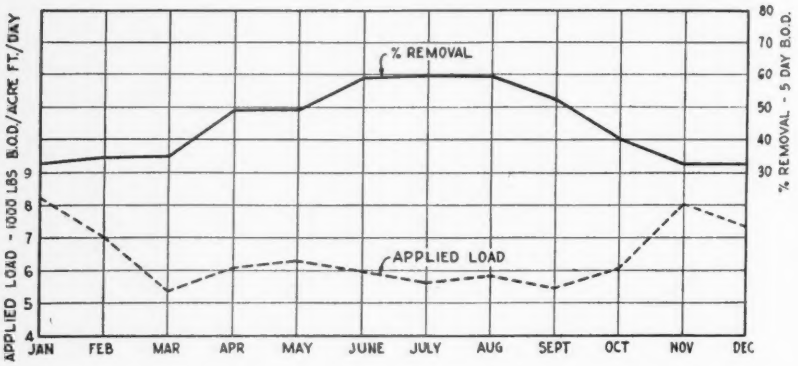
% REMOVAL
APPLIED LOAD
APPLIED LOAD - 1000 LBS B.O.D./ACRE FT./DAY
% REMOVAL - 5 DAY B.O.D.
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FIGURE 3.—High rate filter operating results at Sioux Falls, S.D.; year 1947.

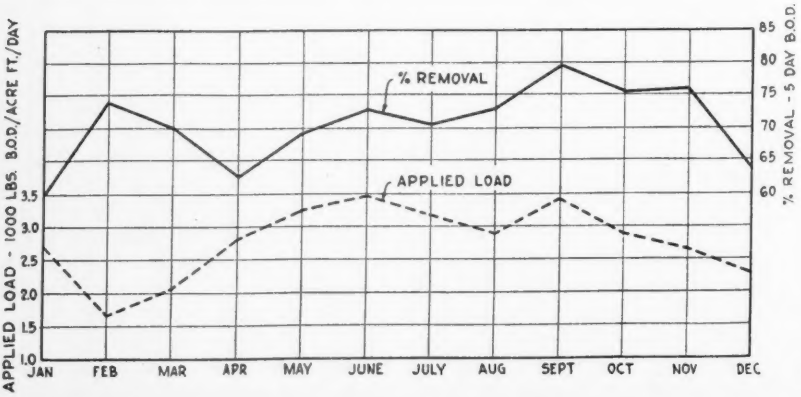
% REMOVAL
APPLIED LOAD
APPLIED LOAD - 1000 LBS. B.O.D./ACRE FT./DAY
% REMOVAL - 5 DAY B.O.D.
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FIGURE 4.—High rate filter operating results at Fort Jackson, S. C.; year 1944.

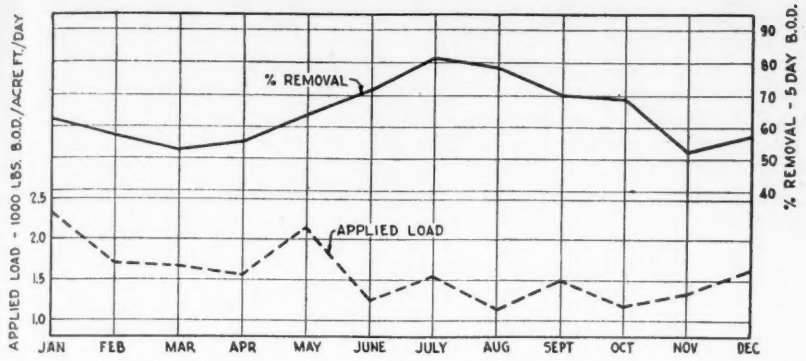

FIGURE 5.—High rate filter operating results at Mason, Mich.; July, 1943 through June, 1944.

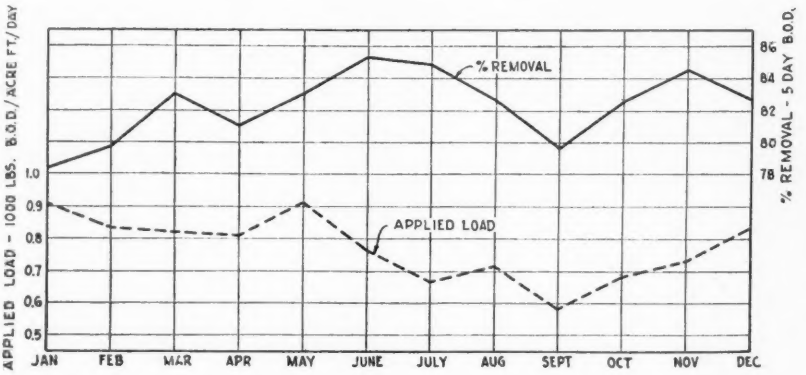

FIGURE 6.—High rate filter operating results at Cedar Rapids, Iowa; 1936–1941.

TABLE I.—Performance Trends of High Rate Trickling Filters Operating at Several Municipal Plants and One U. S. Military Establishment

City	Average Annual Load (lb. B.O.D./ acre-ft./day)	Efficiency[1] (%)	Efficiency from Basic Curves (%)		Recirculation
			No Recirc.	With Recirc.	
Austin	13,870	31.0	35.0	—	No
Springfield	8,772	37.6	—	52.0	Yes
Sioux Falls	6,300	46.0	53.0	—	No
Liberty[2]	3,160	74.0	—	74.0	Yes
Lubbock	2,730	82.0	—	76.0	Yes
Fort Jackson	2,790	71.0	—	75.0	Yes
Mason	1,725	75.0	71.5	81.0	Some
Cedar Rapids	770	81.0	78.0	—	No

[1] The efficiency is calculated as the percentage removal of the 5-day B.O.D. in the settled sewage by the filter and final sedimentation tank.

[2] For the summer months only during 1941 and 1942.

in the final effluent from the sewage treatment plant.

The highest average annual load occurs at Austin, and amounts to 13,870 lb. of applied B.O.D. per acre-foot per 24 hours. The lowest occurs at Cedar Rapids, Iowa, and amounts to 771 lb. of applied B.O.D. per acre-foot. The efficiencies or the per cent removals are generally in the reverse order, amounting to 31.0 per cent for Austin, and 81.2 per cent for Cedar Rapids. It is of interest to note that the higher efficiencies occur in general during the warm months of the year. These operating results, as well as many others, are used in preparing the basic curve on Figure 7.

TABLE II.—Operation Results at Several Municipal Plants and at One U. S. Military Establishment

(Pounds of Applied B.O.D. per Acre-Ft. per 24 Hours)

Months	Austin, Minn.	Springfield, Mo.	Sioux Falls, S. D.	Lubbock, Texas	Ft. Jackson, S. C.	Mason, Mich.	Cedar Rapids, Iowa
Jan.	15,536	—	8,240	2,365	2,720	2,335	903
Feb.	14,217	—	7,040	2,320	1,690	1,720	832
Mar.	13,387	—	5,380	2,380	2,100	1,682	815
April	13,790	—	6,080	2,630	2,820	1,585	807
May	13,367	—	6,360	2,930	3,250	2,140	912
June	13,623	—	6,000	2,950	3,460	1,246	766
July	13,123	12,250	5,630	3,150	3,180	1,557	668
Aug.	12,943	9,830	5,890	3,090	2,890	1,148	715
Sept.	11,652	8,330	5,500	—	3,400	1,492	583
Oct.	12,754	7,770	6,120	—	2,830	1,200	684
Nov.	15,766	8,500	8,050	—	2,690	1,355	736
Dec.	16,324	5,950	7,330	—	2,240	1,635	837
Average	13,870	8,772	6,300	2,727	2,770	1,592	771
Per Cent Efficiency	31.0	37.6	46.0	82.0	70.5	64.2	81.2

Note: Austin is an average of eight years, and Cedar Rapids of five years.

TABLE III.—Quantity of Sewage and B.O.D. Data at Several Municipal Plants and One U. S. Military Establishment

Month	Austin, Minn.				Springfield, Mo.			
	Flow (m.g.d.)	B.O.D. (p.p.m.)			Flow (m.g.d.)	B.O.D. (p.p.m.)		
		Raw	Settled	Final		Raw	Settled[1]	Final
Jan.	3.530	728	528	137	—	—	—	
Feb.	3.435	688	497	124	—	—	—	
Mar.	3.555	598	452	111	—	—	—	
Apr.	3.710	533	452	115	—	—	—	
May	3.740	548	432	59	—	—	—	
June	3.738	548	432	63	—	—	—	
July	3.665	587	437	75	8.8	257	167	
Aug.	3.715	542	427	62	8.5	214	139	
Sept.	3.440	523	405	53	6.9	223	145	
Oct.	3.450	595	442	78	6.3	228	148	
Nov.	3.670	693	517	122	6.3	249	162	
Dec.	3.580	783	548	160	6.0	213	139	

[1] Assuming that 35% of the B.O.D. in the raw sewage is removed in the preliminary sedimentation tank.

TABLE III (Continued)

Month	Sioux Falls, S. D.				Liberty, N. Y.			
	Flow (m.g.d.)	B.O.D. (p.p.m.)			Flow (m.g.d.)	B.O.D. (p.p.m.)		
		Raw	Settled	Final		Raw	Settled	Final
Jan.	4.90	—	661	16.3	—	—	—	—
Feb.	4.45	—	620	14.3	—	—	—	—
Mar.	4.29	—	492	10.4	—	—	—	—
Apr.	4.60	—	519	12.7	—	—	—	—
May	4.62	—	540	14.0	—	—	—	—
June	4.375	—	538	12.2	0.666	392	147	8.9
July	4.39	—	503	8.4	0.803	394	191	9.0
Aug.	4.28	—	540	11.7	0.903	367	173	7.0
Sept.	4.34	—	497	11.5	—	—	—	—
Oct.	4.46	—	538	12.2	—	—	—	—
Nov.	4.75	—	665	14.6	—	—	—	—
Dec.	4.725	—	608	16.5	—	—	—	—

TABLE III (Continued)

Month	Lubbock, Texas				Fort Jackson, S. C.			
	Flow (m.g.d.)	B.O.D. (p.p.m.)			Flow (m.g.d.)	B.O.D. (p.p.m.)		
		Raw	Settled	Final		Raw	Settled	Final
Jan.	1.748	286	186	31.6	2.82	360	234	94
Feb.	1.767	427	278	45.8	2.18	290	188	49
Mar.	1.764	439	285	48.5	2.45	320	208	61
Apr.	1.805	473	308	57.4	3.09	340	221	83
May	1.917	496	323	58.0	3.27	370	241	75
June	2.002	479	311	56.0	3.70	350	227	62
July	2.129	480	312	69.0	3.50	340	221	65
Aug.	2.176	462	300	51.0	3.17	340	221	60
Sept.	—	—	—	—	3.09	410	267	55
Oct.	—	—	—	—	2.85	370	241	58
Nov.	—	—	—	—	2.71	370	241	57
Dec.	—	—	—	—	2.69	310	202	74

TABLE III (Continued)

Month	Mason, Mich.				Cedar Rapids, Iowa			
	Flow (m.g.d.)	B.O.D. (p.p.m.)			Flow (m.g.d.)	B.O.D. (p.p.m.)		
		Raw	Settled	Final		Raw	Settled	Final
Jan.	0.469	210	152	57	9.45	—	287	
Feb.	0.525	107	100	43	7.95	—	465	—
Mar.	0.676	139	76	36	7.80	—	387	—
Apr.	0.701	149	69	31	7.30	—	332	—
May	0.639	163	102	37	8.05	—	338	—
June	0.613	101	62	18	7.90	—	232	—
July	0.650	117	73	14	7.35	—	285	—
Aug.	0.539	106	65	14	6.90	—	356	—
Sept.	0.469	125	97	29	7.25	—	412	—
Oct.	0.398	134	92	28	7.25	—	433	—
Nov.	0.431	149	96	46	8.20	—	348	—
Dec.	0.457	179	109	47	9.50	—	277	—

TABLE IV.—Operating Results at U. S. Military Establishments

Military Establishment	Applied Load in Lb. per Acre-Ft.	Per Cent Removal or Efficiency[1]	Type of Plant
F. E. Warren	8,520	50.5	Single stage, shallow, with recirc.
Sill	6,450	63.0	Single stage, shallow, with recirc.
Callan	5,700	74.5	Single stage, deep, with recirc.
Roberts	5,280	64.0	Two stage, shallow, with recirc.
Bragg	4,340	80.7	Single stage, shallow, with recirc.
Jackson	2,870	66.3	Single stage, deep, with recirc.
Forrest	2,530	70.2	Single stage, deep, with recirc.
Keesler	2,370	86.4	Single stage, shallow, with recirc.
Dix	2,320	89.9	Single stage, shallow, with recirc.
Myles Standish	2,030	81.3	Single stage, shallow, with recirc.
Great Lakes	2,130	71.0	Single stage, deep, no recirc.
Drew Field	1,950	77.0	Single stage, deep, with recirc.

[1] The per cent removal or the efficiency is based on the filter and secondary sedimentation tank.

Sewage Treatment at Military Installations

The report of the Subcommittee of the National Research Council gives the operating results of 34 high rate trickling filter plants. The data for those having the higher loadings are summarized in Table IV. The relation between the load and the efficiency follows the same trend as described for municipal plants and shown on Figure 7, but the efficiencies are somewhat higher in many cases. Monthly results at Fort Jackson are shown in Table II and on Figure 4. The efficiencies from the basic curve on Figure 7 and from Figure 13 of the National Research Council summary report compare as follows:

B.O.D. Load (lb./acre-ft./day)	Efficiency from	
	Basic Curve in This Paper	N.R.C. Report
1000	77.2	78.7
2000	70.0	72.5
3000	65.0	68.2
4000	61.0	65.0
5000	57.2	62.5

Illustrative Performance Trends

In the writer's design procedure it has been found helpful to prepare a diagram showing the relation between the efficiency and the load on high rate trickling filters. To illustrate this in a simplified form, Figure 7 has been prepared, based on a study of the operating results of many trickling filter installations. The basic curve indicates the operating results without recirculation and is considered to be conservative. The efficiency with recirculation is computed directly from the basic curve, assuming that the operation or behavior of the treatment processes is not changed by the recirculation as regards the extent of treatment accomplished. It is realized that many factors affect not only such a computation, but also the basic curve.

To compute the efficiency accomplished by recirculation, on the foregoing assumptions, the total applied load, that is, the quantity of B.O.D. in the preliminary sedimentation tank effluent and in the recirculated liquor, is first assumed. A series of such assumptions are then made and a computation completed for each one. In this way, the curves for recirculation shown on Figure 7 are computed.

Design procedures must be related to operating results and performance trends; and these in turn must be considered in the light of cost trends, which are discussed below. In the

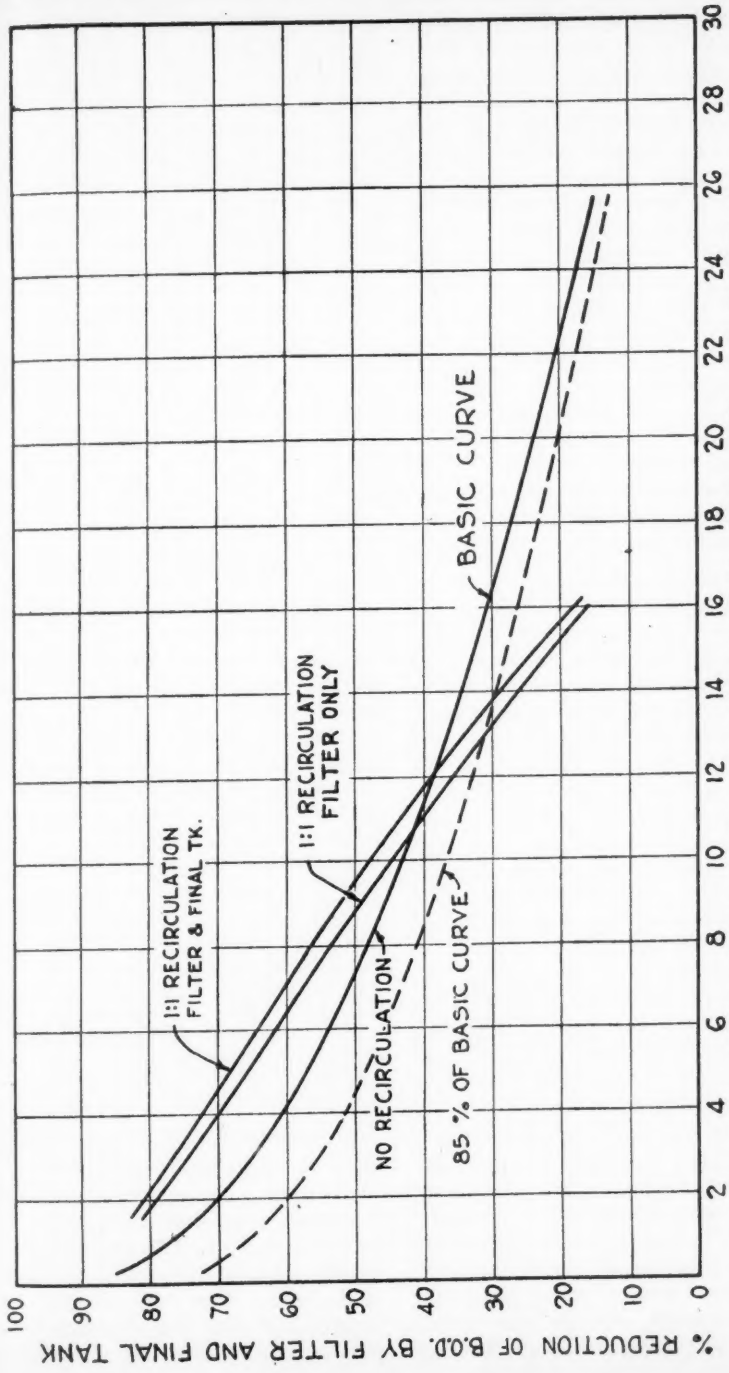

FIGURE 7.—Reduction of B.O.D. by high rate filters and final tanks.

application of performance trends to cost trends, it is necessary to apply to the simplified efficiency-load curve all of the many related factors which, for each local condition, will influence and alter the anticipated performance.

These curves show, based on what now appear to be reasonable working limits of the applied load, that the useful work accomplished per acre-foot of filter or per unit volume of filter increases with the applied load up to some limit of maximum efficiency and economy. The efficiency-load relationship illustrated on Figure 7 indicates such a limit for the applied load of some 10,000 lb. per acre-foot.

General and local factors which will affect and change the load-efficiency relationship are briefly summarized in the following:

(a) The characteristics of the applied sewage as to its treatability are an important factor. With single stage operation, the characteristics of the raw sewage are important. In high rate trickling filter plants having series operation or recirculation, the treatability of the effluent from the first stage filter is a factor. There is not much information on which to base a computation for the lower treatability, but some data indicate that the efficiency for a given load may be reduced by some 15 per cent, and this is illustrated on Figure 7.

(b) The temperature generally resulting from the climate is another factor which affects the load-efficiency relationship. Experience indicates that under warm weather conditions the efficiency is increased.

(c) The necessary over-all degree of treatment is a factor which affects the use of performance trends, as related to the most economical procedure. Thus, with higher degrees of treatment, more recirculation is indicated.

(d) Some items of design also affect the performance and the relationship between the load and the efficiency, such as the uniformity of the applied load and the rate and completeness of its application over the filter surface, and the depth of the filter.

The over-all economy of various operating procedures as related to design is also affected by whether or not local conditions require that the sewage be pumped. It is thus realized that operating results at present are not sufficient to permit precise application of all of the factors which affect the performance of high rate trickling filters. Design procedures are considered to be sounder if they are related to performance trends, however, as illustrated on Figure 7. These curves are considered to be on the conservative side and lower than a considerable amount of operating data.

Illustrative Cost Trends

The general influence of the performance or operating trends on the costs of a proposed sewage treatment project can be illustrated by some simplified cost computations. As in the case of the illustrative performance trends, such cost computations serve to guide engineering studies in particular cases. The illustrative cost trends are related to the following general conditions:

Population	100,000
Average sewage quantity (m.g.d.)	10.0
Average 5-day B.O.D.:	
Pounds per capita per 24 hours	0.17
Parts per million	204.0
Removal of B.O.D. in the preliminary sedimentation tanks	35.0
Average filter depths (ft.)	4.0
Average quantity rates of application (m.g.a.d.)	10.0 to 30.0

The cost computations have been applied to assumed local conditions in which there is available sufficient head to operate two filters, each having 4.0 ft. effective depth in series or in parallel, the latter with the recirculation of one volume of sewage. Under these assumptions, the cost of pumping, if required, is the same for either series

or parallel operation. To illustrate a range of local requirements, computations have been made for over-all sewage treatment plant removals of B.O.D. of 78, 83, and 88 per cent. Further to illustrate the computation, the distribution of B.O.D. for an over-all removal by the sewage treatment plant of 88 per cent is as follows:

Raw sewage (lb. B.O.D./day)	17,000
Applied to filters (lb. B.O.D./day)	11,050
In effluent (lb. B.O.D./day)	2,040
To be removed by filters and final tank (lb. B.O.D./day)	9,010
Per cent removal by filters and final tank	81.5

Application of the curves on Figure 7 determines the size of the filter units. In the illustrative computations, it has been assumed that series operation will have no recirculation and parallel operation will include recirculation of one volume of sewage. Thus for each method of operation the same volume of sedimentation tanks will be required. Prevailing unit costs have been applied to the required capacity of sedimentation tanks and trickling filters; to illustrate the comparative annual cost, 6 per cent of the computed construction cost of the sedimentation tanks and trickling filters has been taken. On this basis, the comparative annual costs are summarized as follows:

Over-all Removal by Treatment Plant (%)	Series Operation		Parallel Operation	
	M.G.A.D.	Annual Cost	M.G.A.D.	Annual Cost
78.0	40.8	$23,400	40.4	$23,600
83.0	30.3	24,800	27.90	25,200
88.0	19.8	27,850	12.30	31,700

Under the assumptions made, series operation appears to be somewhat more economical than parallel operation, although the difference is not great. As stated in the next following section, which describes an actual design, it has been the writer's practice to provide a considerable amount of flexibility in the plant, so that the filters can be operated either in parallel or in series so far as local conditions, especially those related to topography, permit.

Example of an Actual Design

In 1946 the writer's firm was employed to prepare detailed plans and specifications for a sewage treatment plant for a medium sized city located on a relatively large river. The characteristics of the receiving waterway indicated that an overall removal by sewage treatment of 80 per cent would be sufficient. Studies of various methods of sewage treatment resulted in the selection of a high rate trickling filter plant. The principal bases of design are summarized as follows:

Item	Design Basis
Population	100,000
Average sewage quantity (m.g.d.)	9.4
5-Day B.O.D. in raw sewage:	
Pounds per capita per 24 hours	0.17
Parts per million	214.0
Removal of B.O.D. by preliminary sedimentation (%)	35.0

The topography required that all of the sewage be pumped so that the installation of circulating pumps with the main sewage pumps was not a difficult or costly matter. The major sewage treatment structures are listed as follows:

Pumping Station, including Screens
Grit Chambers
Preliminary Sedimentation Tanks
Trickling Filters
Final Sedimentation Tanks
Chlorination Equipment

Based on a study of numerous applicable alternate layouts, it was concluded to build two similar trickling filters placed at the same elevation. Pumps, piping and control equipment were provided so that the filters could be operated in four different ways. Each of the two filters contains 1.84

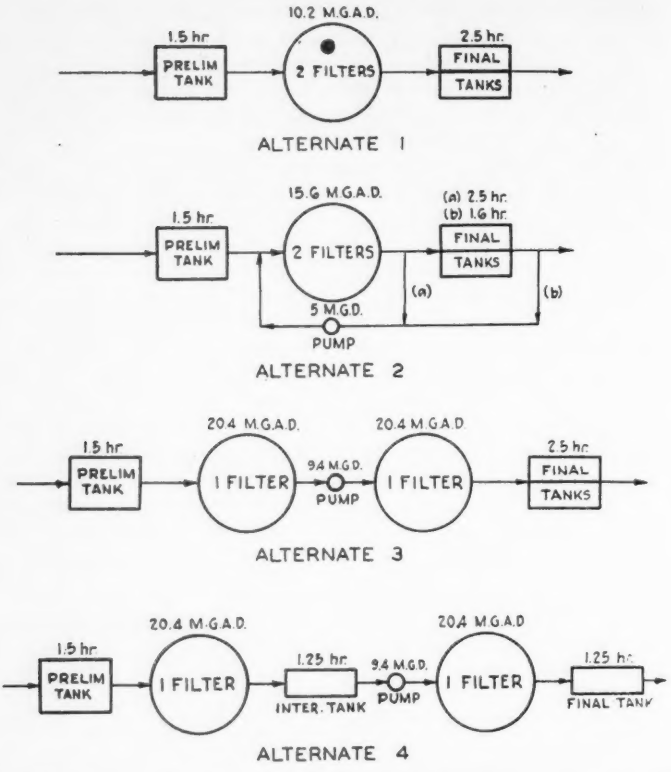

FIGURE 8.—Example of actual high rate filter design, illustrating alternate operating methods.

acre-ft., is 160 ft. in diameter, and 4 ft. deep. Studies similar to those described above resulted in a load of applied B.O.D. of 3,130 lb. per acre-ft. per day. Under this load it was estimated that the removal of 5-day B.O.D. by the filters and final tanks would be 63.0 per cent.

The four alternate methods of operation are shown on Figure 8. Computations were made like those described in the preceding section, with slightly different basic curves, to determine the most likely method of operation based on relative total annual costs. Under the assumed bases of design, it was computed that the two most favorable methods of operation would have the following relative annual costs:

Method of Operation	Relative Annual Cost ($)
Operation of the two filters in parallel, and recirculating 1.5 volumes of filter effluents to filter influent	20,200
Operation of the two filters in series with no recirculation	21,600

At the present time, in the development of high rate filters, it is considered good practice to design such plants so as to provide considerable flexibility in the method of operation,

especially where this can be done without much additional cost.

Concluding Statement

In the opinion of the writer as regards high rate trickling filters, operating data need further study and design procedures need further development to arrive at the best over-all economy and the most desirable operating routine. Bases of design should therefore be conservative and the plant facilities should permit reasonably flexible operation. This paper has outlined, in simplified form, procedures for appraising performance and cost trends and for adopting bases of design for particular local conditions.

High rate trickling filters offer an extended range of sewage treatment in their applicability to the treatment of very strong sewages and to local conditions where the highest degree of treatment is not needed. The further clarification of design procedures is much to be desired.

Acknowledgment

The author was aided in the preparation of this paper by his partners and by Mr. M. H. Dawson, which assistance is gratefully acknowledged.

NEW YORK STATE WATER POLLUTION CONTROL CONFERENCE

Water pollution control for New York State moved a step nearer realization with the conference of representatives of industry and New York municipalities which was held early in August to iron out details of a statewide water pollution control program. Hearings have been scheduled to review details of a pollution control bill which will be submitted to the 1949 session of the State Legislature.

The bill is sponsored by the Special Committee on Pollution Abatement of the Joint Legislative Committee on Interstate Cooperation, which is headed by Assemblyman Harold C. Ostertag. It is based on a 3-year study of pollution in New York State, undertaken at the Legislature's direction. As presently drafted, the bill would prohibit any new pollution from entering the waters of the State, and would require that existing pollution be eliminated through adequate treatment methods, on a specified time schedule. A water pollution control board, which would include the Commissioners of Health and Conservation, would administer the measure under the terms of the proposed statute.

EFFECT OF CHANGE OF TEMPERATURE ON THERMOPHILIC DIGESTION *

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The effect of temperature on the digestion of sewage solids was studied extensively during the preceding decade. These studies clearly demonstrated the advantages of artificial heating of sludge, and the process has since become firmly established.

Two types of digestion temperatures, mesophilic and thermophilic, were recognized. The optimum for the mesophilic range was set at about 30° C., whereas the optimum for the thermophilic range was found to be at 50° C. The acceleration in the rate of digestion beyond 50° C. was only slight, and above 60° C. retardation set in. There was, however, between the optima of mesophilic and thermophilic digestions, a range of 20° C. which was in a sense "No-Man's-Land." The rate of digestion within this range did not increase with temperature, but became constant or even retarded until the optimum for the thermophilic range was reached.

It was shown (3) that in the mesophilic range a ripe sludge produced at 20° C. did not initiate immediately a maximum rate of digestion, but required a period of acclimatization (repeated passages) before the maximum rate at the respective temperatures was attained. The initial increase in digestion time was higher, as the temperature was further removed from that at which the ripe sludge was initially produced. But even after four passages, the digestion time at 42° C. was somewhat higher than at the lower temperatures.

These observations raised several questions: (a) Are the organisms at different temperatures within the mesophilic range the same and, if so, why is the rate of digestion in the upper end of the mesophilic range initially slow with a seed sludge produced at the lower temperature? (b) Are the organisms active in the thermophilic range different than those in the mesophilic range? (c) What are the types of organisms active in the transition range? Are both thermophilic and mesophilic organisms active in this zone (40°–50° C.) at a suboptimum rate, or does one or the other type predominate, or is the digestion brought about by an entirely different type of organism in this temperature range?

These questions represent the theoretical aspects of the problem. Practical implications are: (a) What would happen to thermophilic digestion if the heating facilities went out of operation temporarily? (b) Would the character of the seed sludge be impaired permanently, entailing the development of new seed sludge, or would the seed sludge recover soon after heating was resumed?

This paper is an attempt to answer some of these theoretical and practical questions.

Methods and Materials

The general scheme was to change suddenly the temperature at different periods of digestion of fresh solids with properly acclimatized seed sludge at 50° C. and 40° C. After 0, 2, 5, and 10 days of digestion at 50° C. the temperature was dropped to 40° C. in

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one series and to 20° C. in another. Some digesting mixtures were kept at the lower temperatures permanently, whereas others were transferred to 50° C. after 2 or 5 days. This gave 27 different combinations of temperature changes conducted with 27 identical mixtures of fresh solids and properly acclimatized thermophilic ripe sludge. The same seeding ratio was used in each case, namely, 2 parts of volatile matter in fresh solids to 1 part of volatile matter in ripe sludge. Gas measurements were made during the entire course of digestion. The changes in temperature were accomplished by transferring the mixtures to different incubators, but precaution was taken not to lose any gas during the transfer.

In another series of experiments the digestion temperature of some mixtures was increased after 0, 3, 9, and 13 days at 40° C. to 50° C., whereas in other mixtures the temperature was decreased to 20° C. Some of the mixtures were left at the lower and higher temperatures permanently, and others were transferred back to 40° C. after 2 and 5 days. Twenty-seven separate, but identical, mixtures were used in the series. All were made up with the same batch of fresh solids and ripe sludge, which was produced by prior digestion of the sludge mixture at 40° C. The seeding ratio was 2 : 1.

Results

For the sake of brevity, no attempt will be made to present all the detailed results obtained. The results have been summarized in Tables I, II, III, and IV. The digestion period was determined by taking the number of days required for the daily gas production to reach a low value of 7.5 ml. per gram of volatile fresh solids. In certain cases this will be somewhat misleading, because gas production stopped completely or was retarded after the temperature was changed in the course of digestion; hence, digestion was not complete at the end of the observation period. Such instances will be readily recognized in the tables by the low gas yield. A summary of the results will give only the general overall picture and cannot reveal the sharp changes in rates that took place as a result of changing the temperatures.

TABLE I.—Effect of Digestion at 50° C. for Various Initial Periods on Subsequent Digestion at 40° C. and 20° C.

Mixture No.	Days at Each Temperature			Days Required to Produce 660 Ml. of Gas	Days Required for Digestion[1]	Gas Produced				
	50° C.	40° C.	20° C.			In 15 Days (ml.)	Total[2] (ml.)	Per Cent of Total Produced		
								50° C.	40° C.	20° C.
1	15	0	0	15	15	660	660	100	0	0
2	0	27	0	24	27	278	690	0	100	0
3	0	0	29	29+	29+	23	74	0	0	100
4	2	16	0	19+	18	533	565	10.7	89.3	0
10	5	12	0	17+	17	498	515	32.4	67.6	0
16	10	1	0	20+	11	580	567	100	0	0
7	2	0	27	29+	29+	60	66	91.5	0	8.5
13	5	0	24	29+	29+	175	204	81.5	0	18.5
19	10	0	19	29+	10	565	565	100	0	0

[1] Digestion time on the basis of rate of gas production decreasing to 7.5 ml. per day per gram of volatile matter in fresh solids.

[2] Gas produced in ml. per gram of volatile matter in fresh solids at the end of digestion time indicated under "Days Required for Digestion."

TABLE II.—Effect of Dropping of Temperature to 40° C. and 20° C. from 50° C., for Various Periods and at Various Stages of Thermophilic Digestion, on Subsequent Digestion at 50° C.

Mixture No.	Days at Each Temperature				Days Required to Produce 660 Ml. of Gas	Days Required for Digestion[1]	Gas Produced				
	50° C.	40° C.	20° C.	50° C.			In 15 Days (ml.)	Total[2] (ml.)	Per Cent of Total Produced		
									50° C.	40° C.	20° C.
5	2	2	0	12	17	16	650	655	96.5	3.5	—
6	2	5	0	9	17+	16	625	630	85.5	14.5	—
11	5	2	0	9	17+	16	545	550	88.3	11.7	—
12	5	5	0	6	17+	16	533	540	62.5	37.5	—
17	10	2	0	2	16+	14	600	590	99.5	0.5	—
18	10	5	0	2	17+	17	580	595	97.9	2.1	—
8	2	0	2	11	16+	15	610	610	100	—	0
9	2	0	5	12	16	19	635	715	100	—	0
14	5	0	2	10	18+	17	560	570	100	—	0
15	5	0	5	10	15+	20	520	605	100	—	0
20	10	0	2	9	17+	16	620	625	100	—	0
21	10	0	5	5	20+	20	565	625	100	—	0

[1] Digestion time on the basis of rate of gas production decreasing to 7.5 ml. per day per gram of volatile matter in fresh solids.

[2] Gas produced in ml. per gram of volatile matter in fresh solids at the end of digestion time indicated under "Days Required for Digestion."

TABLE III.—Effect of Digestion at 40° C. for Various Initial Periods on Subsequent Digestion at 50° C. and 20° C.

Mixture No.	Days at Each Temperature			Days Required to Produce 710 Ml. of Gas	Days Required for Digestion[1]	Gas Produced				
	40° C.	50° C.	20° C.			In 19 Days (ml.)	Total[2] (ml.)	Per Cent of Total Produced		
								40° C.	50° C.	20° C.
1	19	0	0	19	19	710	710	100	—	—
2	0	20	0	19	20	710	720	—	100	—
3	0	0	31	31+	31+	0	0	—	—	0
4	3	23	0	26+	26	523	675	12.3	87.7	—
10	9	15	0	21	24	665	750	34.8	65.2	—
16	13	12	0	25	25	650	710	78.5	21.5	—
7	3	0	28	31+	31+	105	200	41.5	—	58.5
13	9	0	18	27+	27	336	425	61.5	—	38.5
19	13	0	17	30+	14	555	550	100	—	0

[1] Digestion time on the basis of rate of gas production decreasing to 7.5 ml. per day per gram of volatile matter in fresh solids.

[2] Gas produced in ml. per gram of volatile matter in fresh solids at the end of digestion time indicated under "Days Required for Digestion."

All the results given in Tables I and II were obtained by using the same fresh solids and ripe sludge and are, therefore, directly comparable, whereas those in Tables III and IV were obtained with different fresh solids and ripe sludge. The ripe sludge used for the mixtures in Tables I and II was an active thermophilic sludge developed at 50° C. by several additions of fresh

TABLE IV.—Effect of Changing the Temperature to 50° C. and 20° C. from 40° C., for Various Periods and at Various Stages of Digestion, on Subsequent Digestion at 40° C.

Mixture No.	Days at Each Temperature				Days Required to Produce 710 Ml. of Gas	Days Required for Digestion[1]	Gas Produced				
	40° C.	50° C.	20° C.	40° C.			In 19 Days (ml.)	Total[2] (ml.)	Per Cent of Total Produced		
									40° C.	50° C.	20° C.
5	3	2	0	23	28+	28	278	650	100	0	—
6	3	5	0	28	36+	36	115	600	100	0	—
11	9	2	0	14	21	25	635	805	88.3	11.7	—
12	9	5	0	12	23	26	570	740	76.4	23.6	—
17	13	2	0	1	25+	16	630	615	90.0	10.0	—
18	13	5	0	11	23	29	650	815	89.3	10.7	—
8	3	0	2	16	21	21	680	700	100	—	0
9	3	0	5	15	23+	23	620	670	100	—	0
14	9	0	2	14	21	25	635	795	100	—	0
15	9	0	5	22	25	26	610	715	95.7	—	4.3
20	13	0	2	6	21	21	675	700	100	—	0
21	13	0	5	10	23	28	605	800	100	—	0

[1] Digestion time on the basis of rate of gas production decreasing to 7.5 ml. per day per gram of volatile matter in fresh solids.

[2] Gas produced in ml. per gram of volatile matter in fresh solids at the end of digestion time indicated under "Days Required for Digestion."

solids to mesophilic sludge. In Table I, three types of temperature effects are given: (1) digesting mixtures made with 50° C. acclimatized ripe sludge continuously at 50° C., 40° C., and 20° C.; (2) digesting the mixture at 50° C. for 2, 5, and 10 days prior to lowering the temperature permanently to 40° C.; and (3) same as (2) except that the temperature was lowered to 20° C.

It is apparent (Table I) that 50° C. is the optimum temperature for digestion of a sludge seeded with 50° C. acclimatized ripe sludge. Such a sludge, when incubated at 40° C. continuously, requires 27 days as compared with 15 days at 50° C. To produce a volume of gas equal to the mixture at 50° C. required 24 days. In 15 days digestion time the volume of gas produced was only 278 ml. at 40° C. as compared with 660 ml. at 50° C. It is also obvious that after 29 days at 20° C. little if any digestion had taken place.

When the mixture seeded with 50° C. ripe sludge was digested initially for 2 and 5 days, respectively, and then placed at 40° C. for the remainder of the digestion period, the time required for digestion was somewhat longer than when the sludge was digested at 50° C. continuously, but was shorter than continuous digestion of the same sludge at 40° C. It appears that a short period of initial digestion at 50° C. does a great deal to counterbalance subsequent retardation at 40° C. If the sludge is digested for 10 days at 50° C. prior to lowering the temperature to 40° C., the digestion time required to reach the same low level of daily gas production is shorter than that for the same sludge digested continuously at 50° C. It should be noted, however, that the yield of gas at this point was lower than in the control, and the digestion time on the basis of equal yields of gas would have been considerably longer than the control. The results cannot always be ex-

pressed on the basis of equal gas yields, because the experiments were discontinued at times before equal volumes were obtained. Such cases are indicated by a plus sign following the indicated digestion times. It will be noted that there was no gas produced by No. 16 mixture the day after the transfer was made to 40° C. or on the days following, up to 20 days of total digestion time, at which time the rate of gas production was less than 7.5 ml. per gm. of volatile solids. Thus, even after 20 days the yield of gas in this case was not equal to that in the control. The same reservations regarding the time of digestion on the basis of unequal gas yields must be made in conjunction with other results so far cited and those that are to follow.

When the temperature was dropped from 50° C. to 20° C. after 2 and 5 days, respectively, the digestion was not complete after 29 days of total incubation period. The gas yield at the end of the digestion period, as well as after the first 15 days, was very low. During the period when the sludge was kept at 20° C. (24 to 27 days) the gas produced represented only a small percentage of the total gas yield. Most of the gas was produced during the 2 and 5 days at 50° C. Transfer to 20° C. after 10 days digestion at 50° C. gave an apparently shorter period of digestion than the control kept at 50° C. continuously. All the gas was produced during the 10 days at 50° C., none being produced after an additional 19 days at 20° C. The volume of gas produced was lower than in the control.

The results of lowering the temperature after digestion for various periods at 50° C., to 40° C. and 20° C. for 2 and 5 days, with subsequent digestion at 50° C., are given in Table II. It will be seen that a drop of 10° C. for periods of 2 and 5 days does not affect the digestion period at 50° C., irrespective of whether the drop in temperature comes at the beginning of digestion at 50° C. (after 2 days) or after the digestion is nearly complete (after 10 days). Furthermore, the digestion time in this series is not appreciably higher than the time required for continuous digestion at 50° C. (see Table I). Again, these comparisons are made on the basis of unequal gas yields.

With the exception of mixture No. 5, the gas yields were lower than in the control (mixture No. 1, Table I). Accordingly, the time required for digestion might be misleading when based on the attainment of an arbitrary low rate (7.5 ml. per gm. of volatile matter).

Comparisons of the time required on the basis of equal yields of gas cannot be made in all cases, since the experiments were terminated before such values were attained. Gas volumes at the end of 15 days of digestion were all lower than if no change in the temperature had been made. It should also be observed that only a small percentage of the gas yield was obtained during the period when the sludge was digesting at 40° C. The actual percentage of the yield of gas at 40° C. was higher with the duration of digestion at 40° C. and was generally lower when the change from 50° C. occurred at a later stage of digestion.

The lowering of temperature after 2 days at 50° C. to 20° C. for a period of 2 days had little effect of the subsequent digestion at 50° C. If the temperature was lowered to 20° C. for 5 days the total digestion time was increased by 4 days. A higher yield of gas was obtained in this case. On the basis of equal yields of gas, the digestion time after 5 days at 20° C., during which time no gas was produced, was not longer than if the digestion had not been interrupted by lowing the temperature to 20° C. Similar interruptions of digestion after 5 and 10 days at 50° C. did not materially affect the subsequent digestion at 50° C. and the

total digestion time. In no case was there any trace of gas production during the period of 20° C. incubation.

In Tables III and IV are reported the corresponding experiments in which the seed sludge had been previously acclimatized and produced at 40° C., and in which the temperatures departed from 40° C. upward to 50° C., and downward to 20° C.

The continuous digestion at 40° C. of the mixture made with 40° C. acclimatized seed sludge required 19 days, as compared with 15 days for digestion at 50° C. with a 50° C. acclimatized sludge (Table I). When the mixture made with 40° C. acclimatized sludge was digested continuously at 50° C. the digestion time was 20 days, as compared with 24 to 27 days for the mixture made with 50° C. acclimatized sludge and digested at 40° C. (Table I).

The results indicate that temperature within this range is more important than the differences in the types of organisms in the 50° C. acclimatized sludge as compared with the 40° C. acclimatized sludge. In other words, the slower rate of digestion at 40° C. is due not to a difference in the flora, but to the lower rate of activity of the thermophilic flora at this temperature. It should be borne in mind that these comparisons are based on two different series with different batches of fresh solids.

Other indications, however, fail to support this view completely. When the change to 50° C. is made after 3, 9, or 13 days at 40° C., the digestion time is longer than if no change had been made to the higher temperature. Similarly, it does not seem clear why a 40° C. acclimatized sludge mixture should digest at 40° C. and 50° C. in nearly the same time if the rate of digestion at 50° C. is greater than at 40° C. and if the organisms at these low temperatures are similar.

When the temperature is lowered from 40° C. to 20° C. either initially or after various periods of digestion, and kept at this lower temperature permanently, the digestion time is definitely affected, depending upon the period when the change is made.

When a mixture seeded with 40° C. acclimatized sludge was digested from the start at 20° C., there was no gas production whatever during 31 days. When the temperature was lowered after 3 days at 40° C., the gas yield during 31 days was 30 per cent of the expected yield at 40° C. It is to be noted that 58.5 per cent of this small yield of gas was produced during 28 days at 20° C. As is to be expected, the longer the period of digestion at 40° C. before the change is made, the higher is the total yield of gas, and the smaller is the percentage of the gas produced at 20° C.

The 14-day digestion period noted for the last mixture, which was kept at 40° C. for 13 days before the temperature was lowered to 20° C., is to be considered in conjunction with the low yield of gas. At the end of digestion period, or after 19 days in fact, gas production during 17 days at 20° C. was nil. The lowering of temperature later during the digestion period, and before complete gas yield is obtained, results in complete cessation of gas production at the lower temperature. Similar results were obtained when the temperature was lowered to 20° C. after 10 days' digestion at 50° C. (Table I).

The effect of temporarily changing the temperature from 40° C., to 50° C. and 20° C., is summarized in Table IV. Irrespective of the stage of digestion at 40° C. when the temperature is increased to 50° C., and irrespective of the duration of digestion before the temperature is brought back to 40° C., the time of digestion is increased as compared with continuous, uninterrupted digestion at 40° C. The least retardation occurred after longer periods of digestion at 40° C. and with shorter periods at 50° C.

The gas yields were again variable on the basis of fixed low rates of gas production (7.5 ml. per gm. of volatile matter per day). The duration of the experiment was at times at least equal to the digestion period as estimated above, and at times it was longer. Only in one case (No. 11) was the time required for digestion longer than the corresponding value, on the basis of time required to produce an equal volume of gas as compared with the control.

The yield of gas after 19 days, which represents the digestion time required for uninterrupted digestion at 40° C., was invariably lower where the temperature was changed from 40° C. to 50° C. Irrespective of the difficulties arising from the differences in fixing the exact time of digestion with variable gas yields, it is apparent that no gas was produced during the period of incubation at 50° C. when the change from 40° C. was made at the end of 3 days. Some gas was produced at 50° C. when the change from 40° C. was made at a later stage of digestion, but the percentage of the yield produced at 50° C. was lower than that produced at 40° C. This is partly due to the shorter period of digestion (2 to 5 days) at 50° C. than at 40° C.

A temporary drop of temperature to 20° C. did not materially increase the digestion time, despite the fact that almost no gas was produced at 20° C.

Discussion

The practical questions raised at the beginning of this paper in regard to the effect of outage of the heating facilities in thermophilic digestion on the course of subsequent digestion after heating is resumed, can be generally answered by the statement that no effect will be produced from which the sludge cannot recover on the resumption of heating. At worst, the effect will be complete cessation of digestion during the period of interruption of heating facilities. This will occur when the interruption is long enough to bring the temperature down toward 20° C.

The theoretical questions raised are somewhat more difficult to answer. Inherently they arise from the problem as to what constitutes the end of digestion. The best parameter so far known is the gas production. The criterion of 90 per cent of the total gas yield has been generally accepted to indicate the end of digestion. But is the gas yield constant with different conditions? Should the time of digestion be varied so that it can be compared on the basis of equal yields of gas, or should the effect of certain factors be evaluated on the basis of the drop of the rate of gas production to a certain arbitrarily selected low value?

Obviously, no single criterion can give the full answer for all conditions. For example, lowering of temperature during thermophilic digestion decreases, if it does not stop completely, the rate of gas production. But this does not necessarily indicate complete digestion unless it is accompanied by the expected yield of gas. The comparisons of digestion time in this study are made on the basis of: (a) a low rate of gas production arbitrarily set at 7.5 ml. per gm. of volatile matter in the fresh solids, (b) the time required to produce equal yields of gas, which parameter could not be used in this study because the experiments in certain cases were terminated before equal yields of gas were obtained, and (c) the rate of gas production as indicated by the volume of gas produced at the end of a fixed time. For the sake of conserving space, rates are expressed in the latter way rather than graphically. The gas yields in many cases were lower and in a few cases higher than the control at the end of the digestion time based on this yardstick. The effect of experimentally induced temperature variations cannot be accurately assessed on an abso-

lutely quantitative basis. In most cases, however, the low gas yields were accompanied by periods of digestion longer than in the control, and therefore the effect of artificial changes of temperature are actually greater than the values recorded on the basis of the criterion used, since on the basis of equal yields of gas the effects would be even greater.

On the basis of the results presented as well as the observations on the daily rates of gas produced, it can definitely be stated that a sludge seeded with a 50° C. acclimatized seed material does not digest at 20° C. no matter at what stage of digestion the temperature is lowered. Gas production completely stops as soon as the change is made; irrespective of how long it is kept at 20° C., no further gas is produced. The longest period that a sludge was kept at the reduced temperature was when the initial mixture made with 50° C. sludge was placed immediately at 20° C., giving a total of 29 days at 20° C. The shortest period was when the mixture was transferred from 50° C. after 10 days to 20° C., giving a digestion time at 20° C. of 19 days. It may be said that these periods are too short to bring about a reacclimitization of the sludge to the radical change in temperature. It is possible that if a more gradual and stepwise lowering of temperature were attempted, the results might have been different.

On the basis of the results presented, it is safe to conclude that the organisms responsible for digestion at 50° C. are not the same as those digesting at 20° C., and that the flora is truly thermophilic and not mesophilic. It is not simply the mesophilic organisms which have been stimulated to a higher rate of activity at 50° C.

When a sludge seeded with 40° C. acclimatized material was lowered immediately and permanently to 20° C. there was no gas production whatsoever during a period of 31 days. Only in two instances were small amounts of gas produced at 20° C. These were when the temperature was lowered at the end of 3 and 9 days at 40° C. and kept constantly at 20°C. for an additional 28 and 18 days, respectively. The actual volumes of gas produced either during the entire digestion period at 40° C. and 20° C., or the volume produced at 20° C., were low, although the percentage of the total yield produced at 20° C. was high. There was no gas production at 20° C. when the digestion at 40° C. was interrupted temporarily by lowering the temperature to 20° C. for 2 to 5 days. It is reasonable to conclude from these observations that the organisms responsible for the digestion at 40° C. are likewise different from the mesophilic organisms.

The next question to be answered is whether the organisms in the 40° C. and 50° C. acclimatized sludges are the same or belong to different types. In order to answer this question the rates of gas production from mixtures made with 50 ° C. seed sludge digested continuously at 50° C. and 40° C., and mixtures made with 40° C. seed sludge digested continuously at 40° C. and 50° C., are given in Figure I. It should be borne in mind that the fresh solids in these two series were different. It is apparent that the rate of gas production is much slower and the lag period is much longer when the mixture seeded with 50° C. sludge is digested at 40° C. in comparison with the same mixture digested at 50° C. In fact, the initial lag period in the former was as long as the entire digestion period required for the latter, and by the time the rate of gas production began to increase at 40° C., the gasification was nearly complete at 50° C. The striking difference might signify that the organisms responsible for the digestion at the two temperatures are the same, but their rate of activity at 40° C. is lower because the optimum temperature is nearer 50° C. The mixture seeded with 40° C. acclimatized sludge and

digested at 50° C. gave a somewhat longer initial lag period (9 days) than the same mixture digested at 40° C. (5 days), but the peak and the low rate of gas production were attained at approximately the same time in both. If the organisms in 40° C. acclimatized sludge were identical with those in 50° C. acclimatized sludge, then the mixture made with 40° C. seed, and digested at 50° C., should give a higher rate than the same mixture digested at 40° C. This is actually the case when the initial lag period is disregarded. The digestion time, exclusive of the lag period, is 10 days (from 9th to 19th days) at 50° C., and 14 days (from 5th to 19th days) at 40° C; the longer lag period at 50° C. might be attributed to a readjustment of the organisms in the 40° C. seed sludge to the elevated temperature. Neither of these mixtures digested as rapidly as the mixture made with 50° C. seed sludge and digested at 50° C., but both digested more rapidly than the mixture made with 50° C. seed sludge and digested at 40° C. It appears that, within this range, the temperature of digestion is more important than the temperature at which the sludge is produced. It follows, further, that the organisms responsible for the digestion at 40° C. are thermophilic types similar to those at 50° C., but are active at a slower rate than they are at 50° C. It does not seem that digestion at 40° C. is brought about by a mixture of thermophilic and mesophilic organisms or by mesophilic organisms alone. That we are dealing with thermophilic organisms at this range of temperature is not to be doubted, because of the failure of digestion at 20° C. by sludge adapted at 40° C. and 50° C.

There is no general agreement

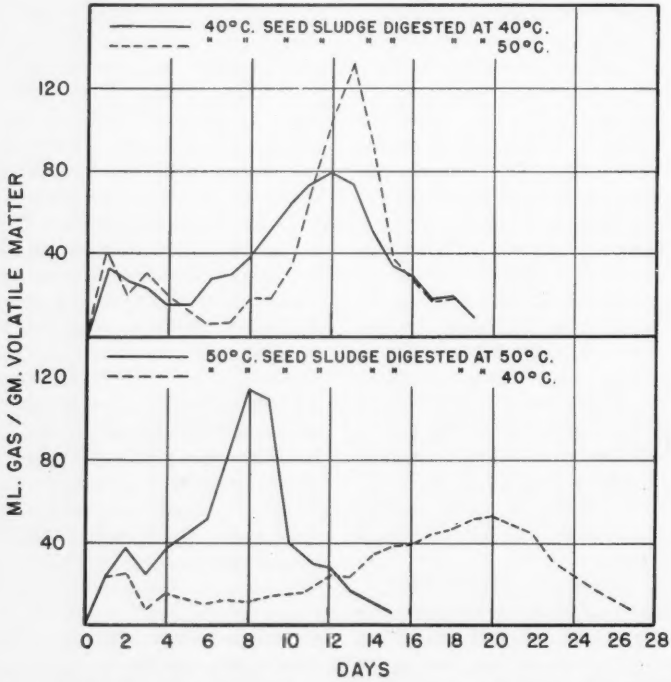

FIGURE 1.—Digestion rates of (a) 40° C. seed sludge digested at 40° C. and 50° C. and (b) 50° C. seed sludge digested at 50° C. and 40° C.

among bacteriologists as to what characterizes thermophilic organisms. The ability to withstand and tolerate high temperatures should certainly not be considered as an essential characteristic. An effort has been made to define a temperature range for the growth of thermophilic organisms. A more precise basis of differentiation would be the maximum, optimum, and minimum temperatures for growth. Certain investigators consider as true thermophiles those bacteria that grow at high temperature but not at body temperatures, and as facultative thermophiles those that grow at 55° C. and 37° C. Bergey (1) considers true thermophiles those bacteria that show an optimum growth at 60° to 70° C. and no growth or only feeble growth at 40° to 45° C.; facultative thermophiles, on the other hand (according to Bergey), have their optimum temperature at about 50° C. and their maximum at about 60° C., but are able to develop at about room temperature. Morrison and Tanner (4) based their classification on optimum temperature only, and recognized the following three groups: (a) strict thermophilics with an optimum temperature above 55° C., (b) facultative thermophilics with an optimum temperature at 50° to 55° C., and (c) thermotolerant bacteria with optimum temperature at 40° to 50° C.

The thermophilic organisms responsible for sludge digestion appear to have the following characteristics: (a) optimum temperature at 50° to 55° C., (2) and definitely not at 60° to 65° C., (b) ability to grow at 40° C. but not at room temperature of 20° C. According to these characteristics it is not possible to place organisms among the obligate thermophiles irrespective of which method of classification used by different investigators is applied. They should therefore be classified among the facultative thermophilics because (a) their optimum is below 60° to 65° C., and (b) they are able to grow at 40° C. but not at room temperature. On the basis of the latter characteristic, however, they do not fit into Bergey's facultative group.

Summary and Conclusions

Properly seeded sludge mixtures made with seed sludge produced at 50° C. and 40° C. were digested continuously from the start at 50° C., 40° C., and 20° C. With other similar mixtures the temperature of digestion was permanently changed during the course of digestion from 50° C. to 40° C. and to 20° C., and from 40° C. to 50° C. and to 20° C. In still other mixtures, after various periods of digestion at 50° C. and 40° C., the temperature was temporarily changed to lower and higher values and brought back to the original temperature. These changes in temperatures were made to show (a) what effect a temporary interruption in the heating facilities would have on thermophilic digestion when heating is subsequently resumed and (b) whether the organisms responsible for the digestion at 40° C. were the same as those at 50° C.

The results warrant the following conclusions:

1. The rate of digestion of a mixture made with 50° C. seed sludge is affected by a drop of temperature. The effect is greater if the temperature is lowered to 20° C. than to 40° C. Gasification completely stops while the sludge is kept at 20° C. The effect also depends to some extent on the stage of digestion when the temperature is lowered. Obviously, if the change is made after the digestion at 50° C. is nearly complete, it cannot have as much effect on the rate of digestion as when the change is made during the course of digestion. The retardation is also influenced by the duration of digestion at the lower temperature. The digestion time lost when a drop in temperature occurs is

equal to the number of days incubated at the lowered temperature.

2. After the sludge is returned from suboptimal to optimal temperature, no lasting effect on the subsequent digestion is obtained.

3. Mixtures made with 40° C. acclimatized sludge do not digest or produce gas when incubated at 20° C., but digest readily when incubated at 50° C. Temporary changes to 20° C. any time during the digestion period at 40° C. results in a temporary stoppage of gas production, which is immediately resumed when the sludge is returned to 40° C. conditions.

4. A detailed analysis of the results indicates that similar organisms are responsible for the digestion at 40° C. as at 50° C., but that the rate of their activity is retarded at 40° C., since this temperature is not their optimum.

5. The organisms responsible for digestion at 50° C. and 40° C. are different from the mesophilic organisms, since no digestion occurs with any of these sludge mixtures at 20° C.

6. On the basis of comparison of the existing systems of classification of thermophilic bacteria, bacteria responsible for the digestion of sewage sludge seem to fit the characterization of facultative thermophilic bacteria better than that of obligate thermophiles.

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CORRECTION

In the Critical Review of Literature for 1947 (THIS JOURNAL, **20**, 2, 224), the statement is made that the so-called "autoxidation process" consists of blowing air and sulfur dioxide into tanks containing scrap iron and water. Attention has been called to the fact that the article quoted states, "the method consists of the simultaneous oxidation of two reducing agents—sulfur dioxide and ferrous sulfate—in the presence of air." The plant consists of a sulfur burner, a reaction cell, and a scrap iron reaction tank.

SLUDGE LAGOONS *

Report of the Committee on Sewage Disposal, Engineering Section, American Public Health Association

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The use of lagoons for sludge disposal is a form of separate sludge digestion. Separate sludge digestion was tested in 1884 (1) at the Pimlico Pumping Station in London, England, and at Essen, Germany in 1891 (2). Prior to 1899, there is practically no reference to separate digestion or lagoons in the contemporary text books.

Technically, separate sludge digestion originated at Lawrence, Mass., about 1899 (3), although some precedent was provided by the sludge lagoons at Essen and elsewhere. Separate digestion was first recommended by Hazen in 1906 for adoption at Paterson, N. J., and was actually put in operation in 1912 at Baltimore, Md., and Birmingham, England. In 1926, Fuller and McClintock (4) noted 14 separate digestion plants in Germany, over 20 in the United States and over 63 in Great Britain. In 1932, 70 separate digestion plants were reported in Germany (5).

In 1922, in Great Britain (6), lagooning was the most common method of sewage sludge disposal. Returns from 99 works show that 57 made use of lagooning; 6 lagoons and pressing; 5 lagoons and land treatment; 15 land treatment; and 12 pressing.

According to the 1943 U. S. Public Health Service census of sewage treatment works, there were 559 municipal and 86 institutional separate digestion plants without heat control, as distinguished from 780 municipal and 21 institutional plants with heat control. In addition, 65 plants were using sludge lagoons in some form. In 1945, the *Engineering News-Record* inventory (7) indicated 82 sludge lagoons.

Wisconsin reports the highest number of municipal heated digestion plants—138 in contrast to 30 unheated. In eight northern and western states a total of 515 heated digestion plants are reported, compared with 182 unheated.

Seventeen states each have more unheated digestion plants than heated. In two states the numbers are equal. Texas, however, has 45 unheated to 3 heated digestion plants.

Development in United States

With the development of the art of sludge digestion from 1920 on and the trend toward heated tanks since 1930, the lagoon was generally considered a temporary expedient. However, for over 20 years Indianapolis has used lagoons as the sole method of sludge disposal. It is not surprising that lagoons are still used in the U. S., but little data are available, except from a few of the larger installations.

Lagoons are particularly useful for emergency storage or disposal of sludge. Sometimes they are worked until filled completely with sludge, but frequently the drained and digested material is removed at intervals and used to fill low-lying areas in the neighborhood or hauled away by farmers for agricultural use. Lagoons may be employed for storage of sludge from heated separate sludge digestion tanks

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during the winter, for removal in the spring to drying beds. They are also used for storage of sludge for discharge into streams at time of flood.

Variations in Weather Conditions

There is a wide difference in the weather conditions across the United States as to precipitation and air temperatures as well as sunlight. From the annual summaries of the U. S. Weather Bureau, the monthly averages of precipitation (Table I) and temperature (Table II) were compiled for 15 cities for the period of record. Humidity, as reported for ten cities, does not vary greatly. However, Salt Lake City shows two months which are relatively low; Los Angeles has three months; and Phoenix, Ariz., has nine months. Low humidity may be accompanied by higher evaporation. Lack of precipitation means less water to evaporate or drain. More sunlight favors algae growths. Higher air temperature tend to promote higher temperatures in surface water supply, sewage, and lagoons. All combined

TABLE I.—Record of Precipitation in Inches at Fifteen Cities

City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Chicago—76 yr.	1.92	1.87	2.67	2.78	3.61	3.54	3.12	3.18	3.20	2.59	2.38	1.93	32.79
Akron—60 yr. (a)	2.47	2.23	3.09	3.00	3.85	3.66	3.96	3.38	3.34	2.67	2.39	2.45	36.49
Indianapolis—76 yr. (a)	2.87	2.56	3.88	3.57	3.89	4.06	3.78	3.25	3.22	2.68	3.17	2.84	39.77
St. Paul, Minn.—56 yr. (a)	0.83	0.87	1.42	2.12	3.58	4.29	3.39	3.18	3.14	2.11	1.36	0.90	27.19
Baltimore—75 yr. (a)	3.42	3.22	3.75	3.54	3.54	3.64	4.43	4.51	3.54	3.03	2.76	3.14	42.52
Memphis—76 yr. (a)	4.99	4.29	5.29	4.86	4.04	3.59	3.18	3.08	2.84	2.83	4.23	4.54	47.76
New Orleans—76 yr. (a)	4.61	4.40	5.18	5.29	4.92	5.81	6.75	6.02	5.36	3.52	3.53	4.62	60.10
Jacksonville—50 yr. (n)	2.80	2.97	2.91	2.38	4.02	5.33	6.71	5.81	7.35	4.46	1.98	3.02	49.74
Albuquerque—55 yr. (n)	0.40	0.32	0.45	0.60	0.60	0.49	1.41	1.24	0.82	0.81	0.46	0.46	8.06
Salt Lake—73 yr. (a)	1.36	1.47	1.95	2.00	1.87	0.84	0.56	0.85	0.88	1.52	1.43	1.37	16.10
Portland, Ore.—50 yr. (n)	6.60	5.36	3.91	2.87	2.19	1.52	0.61	0.64	1.98	3.12	6.10	6.72	41.62
Los Angeles—69 yr. (a)	3.00	3.36	2.78	1.04	0.36	0.08	0.01	0.03	0.21	0.64	1.15	2.89	15.55
Phoenix, Ariz.—51 yr. (a)	0.81	0.83	0.70	0.41	0.13	0.06	1.05	0.99	0.90	0.44	0.67	0.91	7.90
Houston—61 yr. (a)	3.67	2.95	3.20	3.43	4.76	4.36	4.31	3.83	4.14	3.53	3.76	4.35	46.29
San Antonio—62 yr. (a)	1.63	1.57	1.81	3.10	3.36	2.72	2.13	2.16	3.13	2.19	1.78	1.80	27.38

(a) Average. (n) Normal.

TABLE II.—Record of Air Temperatures in Degrees F. at Fifteen Cities

City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Chicago—76 yr. (a)	24.9	26.9	36.2	47.1	57.5	67.5	73.3	71.9	65.3	53.9	40.2	29.2	49.5
Akron—59 yr. (a)	27.1	27.1	36.7	47.8	59.3	68.5	72.7	70.7	64.7	52.6	40.5	30.3	49.8
Indianapolis—76 yr. (a)	29.0	31.1	40.7	52.2	62.9	72.2	76.4	74.2	67.4	55.8	42.4	32.4	53.0
St. Paul, Minn.—56 yr. (a)	13.8	16.6	30.3	46.1	57.9	67.7	73.1	70.4	62.0	49.7	33.0	19.7	45.0
Baltimore—76 yr. (a)	34.8	35.7	43.4	53.7	64.7	73.3	77.8	75.6	69.3	58.1	47.0	37.5	55.9
Memphis—76 yr. (a)	41.4	44.1	52.7	62.0	70.3	78.1	81.0	79.9	74.1	63.3	51.8	43.5	61.9
New Orleans—76 yr. (a)	54.7	57.4	63.1	69.1	75.4	81.1	82.6	82.6	79.5	71.3	62.0	55.9	69.6
Jacksonville—46 yr. (n)	55.4	58.0	62.6	68.7	75.0	79.9	82.1	81.7	78.3	71.1	62.2	56.3	69.3
Albuquerque—54 yr. (n)	34.1	40.5	45.9	54.0	63.3	72.6	76.7	73.9	67.9	56.6	43.3	34.5	55.3
Salt Lake—73 yr. (a)	29.3	34.0	41.8	50.2	58.4	67.9	76.7	75.0	64.8	53.0	40.9	32.2	52.0
Portland, Ore.—46 yr. (n)	39.4	42.1	46.9	51.8	56.9	62.4	66.7	66.7	61.7	54.2	46.8	41.2	53.1
Los Angeles—69 yr. (a)	55.6	56.3	58.0	60.2	62.7	66.5	70.5	71.4	69.8	65.8	61.9	57.3	63.0
Phoenix, Ariz.—51 yr. (a)	52.0	55.7	60.7	67.8	75.8	85.1	90.4	88.7	83.3	71.4	60.0	52.6	76.3
Houston—67 yr. (a)	53.5	56.4	62.8	69.3	75.2	81.2	83.2	83.3	79.0	71.0	61.6	54.8	69.3
San Antonio—62 yr. (a)	52.6	55.8	62.5	69.3	75.2	81.3	83.6	84.0	79.3	71.0	60.9	54.0	69.1

(a) Average. (n) Normal.

TABLE III.—Comparison of Monthly Average Temperatures in Fifteen Cities[1]

City	Number of Months			Min. Month (Deg. F.)	Length of Record (yr.)
	60° F. or Above	45° F. or Below	32° F. or Below		
Chicago, Ill.	4	5	3	24.9	76
Akron, Ohio	4	5	3	27.1	59
Indianapolis, Ind.	5	5	1	29.1	76
Minneapolis, Minn.	4	5	4	13.8	56
Baltimore, Md.	5	4	0	34.8	76
Memphis, Tenn.	7	3	0	41.4	76
New Orleans, La.	9	0	0	54.7	76
Jacksonville, Fla.	9	0	0	56.3	46
Albuquerque, N.M.	5	3	0	34.5	54
Salt Lake City, Utah	4	4	0	32.2	73
Portland, Ore.	4	2	0	41.2	46
Los Angeles, Calif.	8	0	0	56.3	69
Phoenix, Ariz.	9	0	0	52.0	51
Houston, Texas	9	0	0	53.5	67
San Antonio, Texas	9	0	0	52.6	62

[1] Compiled from U.S. Weather Bureau data.

TABLE IV.—Comparison on Precipitation in Fifteen Cities[1]

City	Yearly Average (in.)	Number of Months Precip. Less Than			Length of Record
		1.0	0.5	0.1	
Chicago, Ill.	32.79	0	—	—	76
Akron, Ohio	36.49	0	—	—	60
Indianapolis, Ind.	39.77	0	—	—	76
Minneapolis, Minn.	27.19	3	—	—	56
Baltimore, Md.	42.52	0	—	—	75
Memphis, Tenn.	47.76	0	—	—	76
New Orleans, La.	60.1	0	—	—	76
Jacksonville, Fla.	49.74	6	—	—	50
Albuquerque, N.M.	8.06	10	5	—	55
Salt Lake City, Utah	16.10	4	—	—	73
Portland, Ore.	41.62	2	—	—	50
Los Angeles, Calif.	15.55	6	5	3	69
Phoenix, Ariz.	7.90	11	4	1	51
Houston, Texas	46.29	0	—	—	61
San Antonio, Texas	27.38	0	—	—	62

[1] Compiled from U.S. Weather Bureau data.

tend to promote sludge digestion in open lagoons or in unheated digestion tanks.

Air Temperature

A summary of air temperatures at fifteen cities in the United States (Table III) shows the number of months with the average temperature at 60° F. or above; also with the average temperature at 32° F. or below; and with the average temperature at 45° or below. There is a marked difference between the northern and southern cities in the number of months with an average of 60° F. and above.

Precipitation

A summary of the precipitation data at fifteen cities (Table IV) shows the

yearly average precipitation and the number of months with a precipitation less than 1.0, 0.5, and 0.1 inch, respectively.

Comparison of Air, Water, Sewage, and Sludge Temperatures

The monthly average temperatures for 1932–36 in The Sanitary District of Chicago (Table V) are shown for the air at the Chicago airport (U. S. Weather Bureau); for Lake Michigan at a water intake of the city of Chicago; for the raw sewage at the North Side Works; and for the sludge compartment of an Imhoff tank unit at the West Side Works. Unfortunately, the sewage temperatures were not recorded at the West Side. Temperature readings for 20 months in 1924–25 at the Calumet Works show a minimum monthly average of 43° F. in January, in the Imhoff tank sludge compartment, with the sewage at 42° F. (8).

Comparison of Air and Sludge Lagoon Temperatures

The monthly average temperatures for April, 1945 to August, 1947 are shown (Table VI) for the air temperature at the Chicago airport and the temperature in a sludge lagoon at Summit, Ill., about 3 miles southeast of the Southwest Works and 4 miles west of the airport. The low temperatures in the sludge lagoon during the colder months, around 32° F., are in striking contrast with the higher temperatures in the sludge compartment of the Imhoff tank (Table V), with a minimum of 45.4° F.

The temperature of sludge in German unheated separate sludge digestion tanks is shown by Imhoff (8), who

TABLE V.—Monthly Average Temperatures (Deg. F.) for 1932–36 of Air, Lake Michigan Water, Sewage, and Sludge, The Sanitary District of Chicago

Month	Air[1]	Lake Michigan Water[2]	Sewage[3]	Imhoff Tank Sludge[4]
January	28.0	32.6	50.0	47.8
February	24.2	32.0	48.4	45.5
March	35.4	33.2	49.4	45.4
April	46.6	39.2	52.6	48.1
May	60.9	49.5	59.4	53.5
June	70.6	59.6	67.0	61.7
July	76.8	68.5	73.0	68.3
August	73.0	70.3	75.2	72.4
September	65.7	64.6	72.0	71.4
October	52.7	54.9	66.0	65.0
November	38.2	42.3	59+	56+
December	27.4	33.5	53.0	50.0

[1] At Chicago Airport (U.S.W.B.).
[2] At Dever Crib; last four months 1936.
[3] At North Side Works.
[4] Recording thermometer with terminal in sludge compartment, West Side Works.

TABLE VI.—Comparison of Monthly Average Temperatures of Sludge Lagoon and Air, The Sanitary District of Chicago

Month	Temperature (deg. F.)	
	Lagoon[1]	Air[2]
1945—April	48	49.8
May	53	54.1
June	64	65.4
July	71.4	72.0
August	73.6	72.0
September	70.2	64.0
October	56.4	51.4
November	49	39.8
December	36.2	22.2
1946—January	33.7	26.7
February	33	28.6
March	42	47.2
April	47.5	51.1
May	54.2	56.9
June	61	68.3
July	72	74.6
August	72.5	69.9
September	71	65.6
October	46	58.5
November	51	42.4
December	39	31.9
1947—January	36.2	22.0
February	34.3	24.9
March	32.7	34.5
April	32	46.9
May	—	57.8
June	68	68.1
July	—	72.7
August	74	80.2

[1] Temperature in lagoon west of Lawndale Ave. at Summit.
[2] Temperature at Chicago Airport (U.S.W.B.).

believes that the temperature of the sludge is influenced by and adjusts itself to the air temperature. The temperature of sludge in separate digestion tanks in Germany approximated (2) that of the air, except during the summer, when the sludge was cooler than the air.

Lagooning vs Sludge Digestion

Consideration of sludge lagoons properly should be approached from the standpoint of unheated separate sludge digestion. Experience indicates that where sludge is pumped continuously into a lagoon the situation may result in an odor nuisance. Keefer and Rudolfs (9), from a study of the addition of daily charges of previously settled solids, which were acid in character, to uninsulated unheated separate sludge digestion tanks, found that: (1) by raising the pH of settled solids from about 5.1 to about 7.3, more material can be digested in a given time, and (2) sludge which is neither seeded nor adjusted as to pH will not be digested after a period of 850 days.

The phenomena of unheated separate digestion aid in understanding the behavior of lagoons. Theory and practice in sludge digestion have been covered extensively in the literature, with emphasis on the importance of adequate seeding and mixing, pH control, and influence of climate.

Sludge digestion (10) consists of a breaking-down of organic matter by bacteria and other micro-organisms into simpler and more stable substances. Any free oxygen included in the fresh sludge is quickly exhausted and anaerobic decomposition is established. The first stage of digestion is usually characterized by intensive acid production and by putrefactive odors. The reaction of the sludge drops to pH6 or lower. Acid fermentation lasts about two weeks at a temperature of 60° F. It is succeeded by a lengthy period (about three months) of slow "acid regression." The odor of the decomposing sludge becomes extremely offensive. The pH value rises slowly to about 6.8. As the acidity recedes, "alkaline fermentation" sets in. Large volumes of gas (chiefly methane and CO_2) are released. The pH value may rise above 7.0. In about a month the digestible material is largely exhausted.

"Once alkaline fermentation is established, the presence of well-buffered, enzyme-rich sludge and proper bacterial flora exerts a controlling influence over the course of digestion of incoming fresh solids. The products of acid fermentation are no longer able to depress the pH value, and the long period of acid regression is substantially eliminated. Digestion proceeds more rapidly than in the early stages."

Ripening Period

In the warmer months, alkaline fermentation will usually develop spontaneously. However, if a lagoon in the region of the Great Lakes is placed in operation at the beginning of winter, the accumulation of sludge through the cold months may be refrigerated by the low temperatures so that alkaline fermentation is not established until the following summer. Thus the lagoon may go into the second winter in practically the same condition as it started.

Digestion tanks can be broken in artificially by introducing a charge of well-digested sludge ("seed") and limiting the initial loads of fresh solids to amounts which will not upset alkaline fermentation. To attain the best rates of decomposition, the sludge to be digested should be seeded adequately with sludge previously well digested under nearly identical temperature conditions. Unseeded sludge gasifies at about one-tenth the rate of well-seeded solids.

In operating open lagoons, Imhoff and Fair (10) suggest mixing one volume of well-digested sludge with 2 to 2.5 volumes of fresh sludge, and rotating the point of application of the mixture to the lagoon. The surface

scum should not be disturbed. At 60° F., from 5 to 9 months may then be required for digestion.

If the winter temperature of the sludge in a digestion tank or lagoon hovers around 40° F. for an extended period of time, gasification and natural mixing cease. Alkaline seed sludge then rests inert at the bottom and fresh solids accumulate on top and pass into acid fermentation. With rising temperatures, such tanks require a ripening period in the spring. Increased capacity, no matter how generous, is then of little avail.

Imhoff notes (B) that the methane fermentation depends on two factors: (1) the seeding and mixing; and (2) the temperature. Sierp at Essen in 1924 found zero gas production at 45° F., whereas Eddy at Worcester, Mass., found zero gas production at 40° F.

Seeding and Mixing

Practically all investigators stress the importance of seeding and mixing in separate digestion and lagooning. At times, however, the digestion process may not proceed satisfactorily and a type of fermentation takes place which creates odor. A transfer of such sludge to another tank, with mixing and seeding with material undergoing satisfactory digestion, may be required in a critical situation. The quantity of seeding material introduced may range from 20 to 40 per cent of the tank capacity.

Stage-Digestion

Buswell, Symons and Pearson studied two-stage digestion in 1930 (11) and recommended that complete digestion be carried out in a separate sludge digestion plant, using a small primary tank with 6 or 8 days detention, equipped with the necessary circulating devices to prevent scum and foam formation, followed by a secondary tank or a lagoon adequate to allow for the necessary ripening of the sludge to a state where it will drain on sand beds. They noted an absence of scum formation in the secondary stage of digestion, and stated that only the primary tank would need be heated; the secondary tank might be replaced by lagoons.

Municipal Use of Lagoons in Great Britain

In Great Britain, examples of lagoons used to supplement separate sludge digestion are found at Birmingham and West Middlesex (Mogden).

Birmingham

As reported in 1937 (12), the sludge removed weekly from sedimentation basins at the Saltley Works of the Birmingham Tame and Rea District Drainage Board was given primary digestion in heated tanks, and then pumped 4 miles through a 12-in. main to Minworth for secondary digestion in large open basins with earth banks. Seeding of the sludge was given careful attention, and steam was injected into the force main to raise the sludge temperature in very cold weather. The digestion period was about 3 months in the primary stage and 2 months in the secondary basins.

The sludge is chiefly from the sedimentation of raw sewage, but includes some sludge from the secondary tanks following the trickling filters, and some excess activated sludge.

West Middlesex Main Drainage

The sludge-handling installation at the West Middlesex Main Drainage sewage treatment works at Mogden (13) serves about 1,200,000 population. Sewage treatment includes sedimentation in primary and secondary tanks followed by activated sludge. The sedimentation and excess activated sludge are first subjected to heated digestion for 25 days at Mogden and then pumped to Perry Oaks and digested for 37.5 days. The digested sludge may then be discharged into lagoons, and during the winter is

stored on the sludge drying beds. The capacities provided are:

Location	Cu. Ft. per Cap.	Units	Type
Mogden	1.4	12	Heated
Perry Oaks	2.2	10	Unheated
	3.1		Lagoons
	2.2		Winter storage
Total	8.9	22	—

Municipal Use of Lagoons in the United States

The use of lagoons by various cities in the United States is discussed hereinafter in alphabetical order. General data are summarized in Table VII.

Akron, Ohio

At Akron, Ohio (1940 population 244,791), Schaetzle reports that excess digested sludge is discharged to lagoons with earth banks. The nearest habitation is ¼ mile distant. In 1946, 19,400 tons of dry solids were handled. The total water volume is 28,100,000 cu. ft., with a water surface of 1,840,000 sq. ft. and average water depth of 16 ft. There are twelve units, each about 2.7 acres in area. In 1946, 368,000 cu. yd. of sludge were left in lagoons. The lagoons are fed daily for 8 to 24 hours with sludge averaging 7.2 per cent solids (of which 62.2 per cent is volatile) from the primary tanks, and 6.2 per cent solids (of which 63.8 per cent is volatile) from the humus tanks.

The lagoons were installed because of an industrial overload, after the first year of operation. They have been in use since 1930, but are considered temporary.

Albany, N. Y.

Albany, N. Y. (1930 population 127,412), for a number of years around 1932, handled yearly about 4400 cu. yd. of digested sludge from Imhoff tanks in a lagoon. No odors were reported.

TABLE VII.—Sludge Lagoon Data

Plant	Population Served	Type Sludge[3]	Lagoon Volume (1947)		All or Part Lagooned
			Total (acre-ft.)	Per Cap. (cu. ft.)	
Undigested Sludge:					
Chicago, Ill.:					
Calumet	294,830[1]	Pr.; Act.	1210	18.0	Part
Southwest	1,127,682[1]	Pr.; Act.	2530	51.2	Part
North Side	1,019,967[1]	Pr.; Act.			
Indianapolis, Ind.	402,939[2]	Pr.; Act.	555	60.1	All
Houston, Texas:					
North Side	230,000[2]	Act.	36	6.9	Part
South Side	165,000[2]	Act.	27	7.2	All
Rahway, N.J.	80,000[2]	Pr.	10	5.4	Part
Digested Sludge:					
Akron, Ohio	280,000[2]	Imh.; Tr.	650	10.1	All
Baltimore, Md.	811,400[1]	Pr.; Tr.	25	1.4	Part
Chicago, Ill. (West)	1,487,773[1]	Imh.	125	3.7	Part
Dallas, Texas	294,734[1]	Imh.	32	4.7	All
Mogden, Eng.	1,200,000[2]	Pr.; Act.	—	3.1	Part
Pontiac, Mich.	73,000[2]	Imh.; Pr.; Act.; Tr.	17.5	10.4	Part
Rockford, Ill.	115,000[2]	Pr.	2.5	0.9	Part
Trenton, N. J.	124,697[1]	Imh.	83	28.9	All
Wichita, Kan.	114,966[1]	Pr.	1.2	0.4	Part

[1] 1940 Census. [2] 1947 estimated.
[3] Pr.—primary; Imh.—Imhoff; Act.—activated; Tr.—trickling filter humus.

Baltimore, Md.

At Baltimore, Md. (14), due to insufficient digestion tank capacity, four lagoons were built in 1919 to store both raw and partly digested sludge. The first was 50 by 800 ft. in plan and 8 ft. deep (about 11,850 cu. yd.). This received sludge for about 5 years. In 1922, additional storage was supplied on low land, with a capacity of 4100 cu. yd. After a period of years, the sludge became thoroughly digested and the moisture content decreased to about 70 per cent. The supernatant was siphoned off occasionally.

Batavia, N. Y.

At Batavia, N. Y. (1940 population 17,267), the sludge drying beds, serving Imhoff tanks, were overloaded. Lagoons were installed with a total water surface area of 62,500 sq. ft., divided into three units, which receive about 1200 cu. yd. per year. The nearest habitation is 500 ft. away. Odors occur in the summer, particularly with high humidity and temperature.

Battle Creek, Mich.

At Battle Creek, Mich. (1940 population 43,575), lagoons were used temporarily for the first 5 years of operation, receiving digested sludge from sedimentation. There were twelve units, each about 6000 sq. ft. in area and a water depth about 20 inches. Odors occurred occasionally, particularly on humid days.

The Sanitary District of Chicago

The Sanitary District of Chicago has utilized sludge lagooning over a period of years at three of its major plants.

The Calumet Works (activated sludge) were placed in operation during December, 1935, before the permanent sludge dewatering and drying equipment was completed. All excess sludge (both preliminary and activated) was handled in temporary lagoons, relatively shallow, for about 9 months. Because of the experimental nature of the permanent equipment, a number of changes required shutdowns. The lagoons served to carry part of the load, and since 1941 have received peak solid loads. Two storage lagoons filled up in 1943. In 1944 and 1945, about 25 per cent of the solids removed at the plant were disposed of in the sludge lagoons. One storage lagoon was cleaned in 1944 (7800 cu. yd. removed).

At present the Calumet sludge lagoons consist of a primary lagoon (7 ft. deep; 525,000 cu. ft.), a secondary lagoon (6 ft. deep; 650,000 cu. ft.), and six storage lagoons ranging from 420,000 to 1,180,000 cu. ft. each, all 3 ft. deep. The total capacity is 5,311,000 cu. ft. Four new lagoons are under contract, covering a total area of approximately 20 acres, with 16 ft. dikes. Since 1941, from 2726 to 3678 tons of dry solids annually have been placed in the lagoons, with a total (1941–46 inclusive) of 17,869 tons. Fly ash from the vented gases from drying operations is placed in a separate ash lagoon, covering 157,000 sq. ft. (5 ft. deep) with a capacity of 785,000 cu. ft.

On the site of the West Side Works, a lagoon was installed with an area of about 25 acres, divided into five units with a water depth of 5 ft. From 1940 to 1942 the digested sludge drawn from the Imhoff tanks overloaded the sludge drying beds. In 1943, excess sludge (10,626 cu. yd.) was pumped, in November, to the Southwest lagoons, about five miles west, for seed.

In June, 1944, 7555 cu. yd. of excess sludge was pumped to the plant lagoon. During the summer the sludge dried out to a degree which introduced a fire hazard and one lagoon unit was flooded to extinguish fires. In 1945, during the winter months (October to December), 55,255 cu. yd. were discharged to the plant lagoon, and in

1946 some 36,633 cu. yd. The record of utilization is as follows:

Year	Loading (cu. yd.)	Moisture (%)
1940	116,839	92.4
1941	78,093	92.0
1942	70,924	91.6
1943	—	—
1944	7,255	—
1945	55,255	93.7
1946	36,633	93.4 (est.)

When dried out, a lagoon unit is cleaned by contract, with a dragline. The sludge is conveyed on the sludge railroad to the dump some 3 miles away.

From the burning of pulverized coal in air suspension at the Southwest Works, considerable light fly ash results, which is sluiced away by water to an ash lagoon. Fly ash in the vented gases is removed by precipitators and enters the ash sluicing system. The ash lagoons have a total area of about 3 acres, divided into two units, with dikes about 7.25 ft. high. They are located on the plant site.

In November, 1943, the District put into service about 3 miles southwest of the Southwest Works sixteen sludge lagoons, each unit averaging about 5 acres in area and 16 ft. deep. The total liquid volume of the sixteen units is about 50 million cu. ft. The tops of the earth dikes enclosing the lagoons are used as roadways. To distribute the seed thoroughly, the layout provides for mixing digested Imhoff sludge with waste activated sludge at the Southwest Works before pumping through a 16-in. pipeline to the lagoons. At the start of operations, a content of 25 per cent digested solids was used. Two or more draw-offs are provided in each lagoon for decantation of supernatant.

The loading of the lagoons from November, 1943, through June, 1947 was approximately as follows:

Year	Tons of Solids—Dry Basis			
	Total	Imhoff	Activated	Primary
1943[1]	980	534	446	0
1944	48,587	9,332	39,134	121
1945	66,258	4,015	49,985	12,258
1946	100,837	0	65,806	35,131
1947[2]	60,577	0	43,054	17,523

[1] 2 months.
[2] First 6 months.

In 1946, the concentration of the sludge pumped to the lagoons averaged about 2 per cent. In March, 1947, eight additional lagoons were put in operation, with a total capacity of about 60 million cu. ft. The liquid depth is 16 ft. The area of the units ranges from 10 to 16 acres, totaling 97.5 acres. Into the original sixteen lagoons, during the first 23 months of operation, about 99,740 tons of dry solids were pumped, of which 69.5 per cent were volatile. At the end of the period, the lagoons contained about 50,320 tons of dry solids, of which about 48.6 per cent were volatile. The average concentration of solids in the lagoons was 4.01 per cent.

At the end of March, 1946, the concentration of solids had increased to an average of 5.6 per cent, and the volatile content had risen to 60 per cent. The increase of volatile content in individual lagoons is particularly marked where sludge was added through the winter months.

During the four winter periods of operation, ice has formed at the surface. At times the lagoon temperature has dropped to 32° F. (Table VI). The lagoon warms up more slowly than the atmosphere, and cools down more slowly. In the colder months of 1945–46, there were 4 months below 45° F., and in 1946–47, there were five months below 45° F.

Despite the cold winter periods, there was apparently a minimum of odors between 1943 and 1946. Considerable odor developed in the spring

of 1947, traceable to an attempt to seed with supernatant and a small amount of digested sludge. With a return to a higher proportion of well-digested sludge, and the onset of warmer weather, the odors were materially reduced.

Dallas, Texas

Since 1927, Dallas, Texas (1940 population 294,734), has used a lagoon about 5 acres in extent, from 3 to 4 ft. deep, into which sludge is discharged from Imhoff tanks. The lagoon is emptied about twice a year, when the neighboring river is at flood.

Fitchburg, Mass.

Around 1932, Fitchburg, Mass. (1930 population 40,692), reported an excess of digested sludge from the Imhoff tanks, which was lagooned in gravelly soil, without underdrains. A noticeable reduction in sludge volume in the lagoon was reported over several years, as dewatering proceeded.

Houston, Texas

Houston, Texas, operates two activated sludge plants. The North Side plant began operation in 1917, and the South Side plant in 1918. As these were among the first sizeable plants in the United States, lagoons were employed as a temporary measure at the South Side until such time as a better method was demonstrated. At the time, lagooning was the cheapest method available for disposing of excess activated sludge. Pertinent data shown in table at top of page.

The sludge is normally left in the lagoons. Various observers have reported odors at the plants since operation began.

Indianapolis, Ind.

The Indianapolis, Ind. activated sludge plant went into operation in 1926. For reasons of economy, both the sludge from preliminary clarification and the excess activated sludge were pumped to lagoons for deep pit digestion (15). Originally these were about 300 ft. square and leveed to give a depth from 7 to 10 feet. The average total volume was 4,368,000 cu. ft. In 1928, there were seven pits in service.

	North Side	South Side
Population (Est. 1946)	230,000	165,000
Sludge Lagoons:		
Water volume (acre-ft.)	36.26	27.4
Area water surface (acres)	7.25	7.74
Water depth, average (ft.)	5.0	3.5
Number units	3	3
Underdrains	None	None
Nearest Buildings:		
Residential (ft.)	300	—
Industrial (ft.)	—	300
pH (19 months)	6.80 to 7.97	6.81 to 8.0
Excess Activated Solids Discharged to Lagoons in 1946:		
Tons, total	3,247	1,780
Tons per acre-ft.	89.5	65

The sludge was pumped in at 7.72 and 1.12 per cent solids for the primary and waste activated sludges, respectively. Such a mixture never drained in the pits to less than 80 per cent moisture and usually remained at 85 per cent. The method of operation in 1928 was to pump continuously into one pit and pass the effluent successively into two more pits.

In 1947, Frazier states thirteen pits were available, with a total capacity of around 24,220,000 cu. ft., covering an area of 52.5 acres, with an average sludge depth of 10.6 ft. In 1946, the per cent of dry solids in the various sludges delivered to the lagoons was: primary—4.9; aerated—2.9; activated —1.1.

The census population of Indianapolis in 1940 was 386, 972. The esti-

mated population tributary in 1947 was about 403,000. On this basis, the lagoon volume was 60.1 cu. ft. per capita. The average cycle between filling a lagoon and cleaning has been a minimum of from 4 to 5 years, although some units are receiving sludge after nine years.

In 1946, Bloodgood (16) stated that sludge lagoons were used continuously for 20 years at Indianapolis without creating nuisance; that the size of a lagoon unit is not too important; and that an underdrain system is unnecessary. The supernatant has been discharged eventually to the White River.

Due to difficulties during the war, the lagoons at Indianapolis were not cleared of sludge as rapidly as in prewar days (17). The all-time high annual sludge haulaway in 1939 of 35,050 cu. yd. declined to 2592 cu. yd. in 1944, and has risen to 16,453 cu. yd. in 1946. For the years 1939–43, the average annual haulaway was 20,537 cu. yd. For the years 1942–46, the annual average was 11,334.

The sewage solids discharged to the lagoons in those periods averaged yearly 27,287 tons and 26,619 tons, respectively. For the 5-year period 1939–43, Frazier estimates that only about 25 per cent of the sludge solids received were hauled away. On a similar method of estimate, only 14 per cent was hauled in the 5-year period 1942–46. Consequently, the plant is pressed for lagoon space. Various observers report odors around the lagoons, but no complaint has been made by local residents.

Pontiac, Mich.

At Pontiac, Mich. (1940 population 66,626), lagoons are used temporarily because of lack of digestion capacity. The plant has Imhoff tanks and a supplemental heated sludge digestion tank. The original trickling filter plant has been reinforced by an activated sludge plant.

The lagoon has a total water volume of 760,000 cu. ft., with a water surface area of 76,000 sq. ft. and 10-ft. depth. It is said to handle 500 tons of dry solids per year, and has been operated for 6.5 years. The nearest habitation is 1000 ft. away.

Rochester, N. Y.

Rochester, N. Y., in 1931 and 1932, lagooned excess sludge in a basin about 1 acre in area and 10 ft. deep. The sludge was drawn from Imhoff tanks during the early winter and early spring. In 1931, out of a total of 38,624 cu. yd. drawn from the tanks, 25,200 cu. yd. went to the drying beds and 13,424 cu. yd. to the lagoon. The lagoon contents were reported to dry very slowly.

Rockford, Ill.

The Rockford, Ill., plant (serving about 115,000 pop.) consists of sedimentation tanks, with two-stage heated separate sludge digestion. Riedesel reports that digested sludge is discharged in the spring to two temporary lagoons, each containing 53,250 cu. ft., with a water surface of 12,900 sq. ft. and a water depth of 5 ft. The cycle per unit (empty to empty) is three years. Two years are required to drain and dry. The sludge is removed in three weeks. No appreciable odors are reported, although habitations are adjacent to the treatment plant site. Permanent deep lagoons are planned as part of new plant additions.

Syracuse, N. Y.

At Syracuse, N. Y. (4), sewage sludge from plain sedimentation basins is removed continuously by Dorr mechanisms, then pumped to lagoons about 2 miles away, and combined with many times its volume of industrial wastes from the Solvay Process Co. The resulting mixture is sterilized completely by chemicals in the Solvay wastes. The overflow from the lagoons flows into Onondaga Lake.

Toledo, Ohio

At Toledo, Ohio (1940 population 282,389), Niles reports that excess digested sludge is being pumped onto a natural marsh, some 250 to 300 acres in area. Yearly, about 5800 tons of dry solids are so disposed of, and about 1200 tons additional are used for fertilizer. The sludge as pumped contains about 8 to 8.5 per cent solids, which have a volatile content around 45 to 47 per cent. Odors are reported occasionally in the summer, particularly with high humidity and temperature.

Toronto, Can.

At Toronto, Ontario (1941 population 667,457), sludge lagoons received undigested sludge from plain sedimentation tanks. When filled with sludge, the lagoons were allowed to rest for about a year. Then the sludge was pumped out by a suction dredge and deposited as fill in an adjacent area in the bay (18). In 1925, there were 12 lagoons, each about 0.5 acre in area and 10 ft. deep, which handled the sludge production for 2 years. The units were filled in rotation. When filling, the effluent from the unit passed through three additional units. Heavy scum formed. A unit was filled in 2 months and allowed to digest for 1 year. So long as the material was not disturbed, only an occasional slight ammoniacal odor was reported. A thin layer of sand or silt was pumped over the dry sludge.

Trenton, N. J.

Trenton, N. J., in 1932 (1930 population 123,356), used a lagoon 200 ft. by 1800 ft. and 10 ft. deep, located in an old river bottom. This was divided into a number of units by earth dams about 200 ft. apart. Each unit was filled, in turn, with well-digested sludge from Imhoff tanks, with a moisture content around 90 per cent. Small amounts of sludge were added frequently. Drying proceeded rapidly. One unit holds about two years sludge (24,000 cu. yd., wet basis). No nuisance has ever been reported.

Wichita, Kansas

Wichita, Kansas, in 1947 (1940 population, 114,966) used a shallow lagoon with a water volume of about 50,000 cu. ft., divided into six units. Digested sludge from heated digestion tanks was fed monthly. The cycle per unit (empty to empty) was about two years. All the sludge was removed from the lagoons by farmers, city parks, and airports. The lagoons were installed because of insufficient drying beds.

Experience in Various States (1947)

In Illinois, Klassen states that there are no plants which have attempted to digest sludge in lagoons, other than the Chicago Sanitary District and Rockford Sanitary District. However, shallow depressions and surface areas have been employed at six locations as emergency disposal areas for digester supernatant, digested sludge, and in a few cases, waste activated sludge, due to inadequate areas of sludge drying beds. In one case, a definite nuisance resulted.

In Indiana, Poole states that nine municipalities use lagoons for sludge disposal. At Indianapolis, both undigested primary and activated sludge has been discharged to lagoons for over 20 years. At three plants, digested sludge has been lagooned as a matter of economy. In five plants, lagooning of digested sludge is used to compensate for lack of drying beds. In general, "lagooning has been successful in Indiana where reasonable precautions are taken relative to location and operation."

In New York, Barker reports that twelve municipalities employ lagoons to handle excess sludge. In his opinion, where "adequately digested sludge is discharged to a lagoon, there

should be no serious difficulty due to odors from the lagoon."

In Ohio, Waring states that the State Department of Health does not look upon sludge lagoons with favor, because it considers them an admission of failure either in plant operation or in design. The majority of the larger plants in Ohio have of necessity adopted sludge lagooning, generally because of under-design of sludge drying beds. In some instances sludge lagoons are used for the disposal of supernatant from sludge digesters.

In Wisconsin, Warrick reports that ten municipalities are using sludge lagoons.

Disadvantages of Lagoons

The most common complaint about lagoons concerns odors. Wet sludge may be discharged (18) into a lagoon, which is a basin formed by a natural depression—often a sand pit, clay pit, or quarry—or by surrounding a tract of land with a dike of earth. The sludge is left to dry by evaporation and by such losses of water through the soil as may naturally take place. Partial digestion and drying of the sludge occur over a long period of time, frequently accompanied by offensive odors when undigested sludge is disposed of in this way.

Odors emanating from sludge lagoons are comparable to those coming from poorly-digested sludge on sludge drying beds, according to Cohn (19). The lagooning of well-digested sludge at a plant where sufficient drying space is not available is excusable, but the use of a ravine for the disposal of poorly digested material, in order to clear tanks, cannot be classed as efficient operation. Odors will result that may be difficult to control.

At Baltimore, Md., from 1913 to 1925, odors occasioned complaint. Odors have been noted on occasion at Houston, Indianapolis, Pasadena, and elsewhere. At Chicago, odors were noted in the spring of 1947 at the Lawndale lagoons, due to experiments on seeding. At Calumet, odors have occurred when lowering the water level in the lagoon during hot weather.

At Houston (20), lagooning of excess activated sludge was not satisfactory. From 1917 to 1920, the only means of disposal was lagooning. When the pH of the sludge dropped below 7.0, a thick crust of undigested sludge solids formed, and a highly offensive odor was noted. Objectionable odors were reported by various observers. In 1947, however, Houston was still using lagoons for a considerable portion of its sewage sludge. The lagoons at one plant are within 300 ft. of habitations, and at the other, within 300 ft. of an industrial plant area. Odors occur throughout the year, but are reported worse in summer, particularly at night, with high humidity and temperature.

At Pasadena (18), lagooning of excess activated sludge created objectionable conditions, due to odors, as well as flies and other insects. Goudey (21) reports that "at one time a comprehensive survey indicated that odors from lagooned sludge traveled 7000 ft., covering an area of 3100 acres and affecting 10,000 people."

Conclusions

The use of lagoons for sludge treatment and disposal is still prevalent in the United States. Although frequently used as an emergency outlet for excess sludge, lagoons have been used at certain plants for over 20 years.

Lagoons may receive raw settled solids or digested settled solids. In some cases, secondary sludge from trickling filters or excess activated sludge may be added to the primary sludge. When receiving raw solids, a lagoon may be difficult to control in a northern climate, and may give rise to unpleasant odors, particularly in the late spring when the sludge temperature begins to rise above 60° F. and the sludge held through the winter starts

to decompose. When receiving digested solids, a lagoon becomes a storage basin and can be loaded over a period of years and then dried out and cleaned. Or, if circumstances permit, lagoons have been unloaded into a neighboring stream at time of flood. Such practice may be undesirable.

The reports of observers differ as to the prevalence of odors. Apparently odors should be at a minimum when digested sludge is used. In northern climates, lagoons fed with raw sludge undergo a dormant or refrigerating stage through the winter months. When the sludge warms up in the spring, the volume of undigested sludge is stimulated to a degree which may create odors.

The problem of odors and their effect on a local situation depends on many circumstances. Odors may be noticeable in the area occupied by the treatment works site, but if habitations are distant, no complaint ensues. On the other hand, certain distinctive odors, such as arise in acid sludge digestion, may travel a considerable distance. Thus the type of odor is a factor.

The capacities provided in the plants for which data were obtained have varied greatly, according to the use (whether for excess sludge or all the sludge) and the nature of the solids. The smaller capacities per capita should occur with digested sludge, and the larger capacities where excess activated sludge is concerned. Considerably more capacity is required in lagoons per capita than in separate sludge digestion.

In the Southwest, with a monthly temperature averaging above 60° F., open unheated separate digestion or lagooning should prove adaptable and efficient, with proper design for mixing and seeding and withdrawal of supernatant.

The disposal of supernatant liquor from lagoons is not uniform in practice. Apparently many operators put the supernatant into the nearest stream, if large enough in volume. It should be measured, sampled, and analyzed for B.O.D. and suspended solids before making a decision.

There is a lack of reliable data on lagoons and their utilization, as well as their location, probably because they are generally regarded as a temporary measure.

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OBJECTIVES FOR BOUNDARY WATERS QUALITY CONTROL

The International Joint Commission has announced objectives for the quality control of boundary waters. The term "boundary waters" as used includes the waters defined in the references to the International Joint Commission dated April 1, 1946, October 2-3, 1946, and April 12, 1948, and are as follows:

St. Clair River, Lake St. Clair, the Detroit River, St. Marys River from Lake Superior to Lake Huron, and the Niagara River from Lake Erie to Lake Ontario.

These objectives are for the boundary waters in general, and it is anticipated that in certain specific instances, influenced by local conditions, more stringent requirements may be found necessary.

It is intended that these objectives are preliminary only and are subject to change from time to time as the investigation of these waters continues, and until such time as the final report has been adopted.

General Requirements

All wastes, including sanitary sewage, storm water, and industrial effluents, shall be in such condition when discharged into any stream that they will not create conditions in the boundary waters which will adversely affect the use of these waters for the following purposes: domestic water supply, industrial water supply, navigation, fish and wild life, bathing, recreation, agriculture and other riparian activities.

In general, adverse conditions are caused by:

(1) Excessive bacterial, physical or chemical contamination.

(2) Unnatural deposits in the stream, interfering with navigation, fish and wild life, bathing, recreation, or destruction of aesthetic values.

(3) Toxic substances and materials imparting objectionable tastes and odors to waters used for domestic or industrial purposes.

(4) Floating materials, including oils, grease, garbage, sewage solids, or other refuse.

Specific Requirements

Specific requirements have also been adopted which set forth in greater detail the permissive characteristics of wastes discharged to boundary waters.

It is intended that the methods of determination of the pollutants referred to in the above objectives will be provided by the Board of Technical Advisers.

CORRECTION OF B.O.D. VELOCITY CONSTANTS FOR NITRIFICATION *

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In an earlier study (1) of the variations in the velocity constants of biochemical oxidation of sewage, variations of k between 0.04 and about 0.29 were observed in series of domestic, hospital and military sewage. This study also indicated that nitrite formation frequently was initiated within the first 10 days of incubation and that it generally started earlier in higher dilutions of sewage. It was concluded that the generally accepted theory of rather uniform two-stage biochemical oxidation was incorrect and in need of revision. The truth is that nitrogenous oxidation frequently occurs simultaneously with carbonaceous oxidation during the first 10 days of incubation.

It was also found that the plotting of the observed gross results on a series of B.O.D. observations from 1 to 10 days did not indicate correctly the actual time that nitrite formation was initiated. Because of the variability in the onset of nitrite formation, even in duplicate bottles of the same dilution, it was concluded that the only way in which nitrogenous oxidation could be followed was by actual nitrite determinations on the same bottle in which oxygen utilization was to be measured.

In view of these results it became evident that all earlier determinations of k values based on gross B.O.D. of sewage dilutions could not with assurance be considered velocity constants truly representing the carbonaceous stage. Constants determined up to the present represent the reaction velocity of the resultant carbonaceous and incident nitrogenous oxidation that occurred during the period of observation.

To obtain velocity constants representative only of carbonaceous oxidation of sewage dilutions, the reaction must be followed with not only oxygen but also nitrite and nitrate determinations, and the proper corrections for nitrogenous oxidation must be applied to any samples in which this occurs. It was decided that such a study should be made in order to determine the variations in the velocity constants of the true carbonaceous B.O.D. The determinations of nitrite and nitrate that would be needed in such a study would give some needed information on the time of initiation of nitrite formation in a series of sewage sample dilutions.

Plan of Study

A series of B.O.D. observations following 1- to 10-day incubation periods of sewage dilutions were made using the following technique. In all studies 500-ml. glass-stoppered bottles were used for incubating the sample dilutions in place of the standard 250- or 300-ml. bottles. When a 500-ml. bottle was removed from the incubator, a portion was immediately siphoned off to fill completely a standard B.O.D. bottle, with the observation of every precaution to prevent aeration of the sample during the transfer. The dissolved oxygen was determined immediately by the azide modification of the Winkler procedure on the transferred portion, and the result was used to calculate the gross B.O.D. The sample

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portion remaining in the 500-ml. bottle was used for nitrite determinations. The oxygen equivalent of the nitrite found, if any, was deducted from the gross B.O.D. to obtain the net carbonaceous B.O.D. Whenever there was any indication that the formation of nitrates had started, the observations on a particular series were stopped and oxidation constants were derived on the basis of values observed to the suspected time of inception of nitrate formation. This occurred in only one of the series obtained, and in one group of three series some single observations were disregarded; i.e., of duplicates available one value only was used in making the calculations. The constants for the formulation of the unimolecular reaction were derived by the application of the Thomas (2) "slope" method to the corrected carbonaceous B.O.D. data.

Experimental Data

For comparative purposes a number of B.O.D series were run using two dilution waters following the above procedure with duplicate bottles of each dilution incubated for 1- to 10-day intervals. Seven such comparative series were studied using Theriault-Nichols and Formula C water. Eight comparative series included Thierault-Nichols and bicarbonate water. Of the above fifteen comparative series, five were made with all three dilution waters. The k and L values obtained on all of these comparative B.O.D. series are shown in Table I.

It will be noted that on ten B.O.D. series in the Theriault-Nichols dilution water the k for carbonaceous oxidation varied from 0.12 to 0.203. There was a very similar range of variation in k in the other two dilution waters. The mean k values obtained simultaneously on seven samples in T–N and Formula C water were 0.164 and 0.174, respectively. The mean k obtained simultaneously in T–N and bicarbonate water was 0.166 for both waters.

On the basis of these comparative k values, and on the range of values in each water, it must be concluded that after correction for nitrification, the carbonaceous oxidation velocities are relatively the same in these three dilution waters.

On a series of five sewage samples the k and L values were derived for two or more dilutions after correction for nitrification. These data are presented in Table II. As in the case

TABLE I.—Comparison of k and L Values for B.O.D. Series in Three Dilution Waters When Corrected for Nitrite Formation

Sample	$k_{(0-10)}$			$L_{(0-10)}$		
	$T-N$[1]	C[1]	B[1]	$T-N$[1]	C[1]	B[1]
Cinc. sewage	0.201	—	0.188	262	—	251
Cinc. sewage	0.190	—	0.197	340	—	292
Cinc. sewage	0.120	—	0.125	328	—	314
Mill Creek	0.139	0.087	0.131	38	45	40
E'town, Ky.	0.166	0.188	—	156	166	—
Cinc. sewage	0.186	0.170	0.154	233	233	244
Cinc. sewage	0.169	0.173	—	457	487	—
Cinc. sewage	0.203	0.214	0.200	437	467	455
Cinc. sewage	0.151	0.221	0.154	552	550	572
Cinc. sewage	0.137	0.165	0.178	267	234	215
Ave.; T-N and C[2]	0.164	0.174	—	306	312	—
Ave.; T-N and B[3]	0.166	—	0.166	307	—	298
Ave.; T-N, C and B[4]	0.163	0.171	0.163	305	306	305

[1] T-N = Theriault-Nichols; C = Formula C; B = Bicarbonate (300 p.p.m. $NaHCO_3$).
[2] Seven series. [3] Eight series. [4] Five series.

TABLE II.—Comparison of k and L Values for B.O.D. Series Obtained in Different Sewage Concentrations When Corrected for Nitrite Formation

Date Sample Cinc. Sewage	$k_{(0-10)}$			$L_{(0-10)}$		
	Sewage Concentration[1]			Sewage Concentration[1]		
	Lowest	Middle	Highest	Lowest	Middle	Highest
9/30/46[2]	0.182	0.219	0.212	567	575	569
10/2/46[2]	0.214	0.191	0.188	291	254	251
10/10/46[3]	0.123	—	0.188	294	—	251
10/21/46[3]	0.179	—	0.197	344	—	292
10/30/46[3]	0.077	—	0.125	338	—	314
Mean	0.155	—	0.182	367	—	335

[1] Lowest concentrations 0.4 to 0.5 per cent; highest 0.8 to 1.0 per cent.
[2] T-N dilution water. [3] Bicarbonate dilution water.

for gross B.O.D. (1), these data indicate that the k for carbonaceous oxidation is affected by dilution and generally seems to be higher in the higher sewage concentrations, although individual exceptions have been noted.

The incidence of nitrification for incubation periods up to the tenth day for common dilutions on 45 sewage samples is shown in Table III. It will be noted that only 4 samples, or about 9 per cent, showed nitrification by the fifth day, and that this percentage increased steadily and reached 42 per cent by the tenth day.

Since observations for 7 to 10 days are needed for reaction velocity studies, it becomes evident that all B.O.D. dilution data to be used for studies of rates of carbonaceous oxidation must be obtained as described, or in a similar manner, and corrected for nitrification. These data on the incidence of nitrification, however, apply only to Cincinnati sewage for the transition and winter season. Much more similar data are needed for all seasons and for other latitudes.

Erratic Observed B.O.D. Due to Eccentric Nitrification

Even among duplicate portions of the same material incubated under identical conditions, the incidence of nitrification has repeatedly been observed to be a highly variable and unpredictable phenomenon. Under extreme conditions, this has been observed to cause apparently highly erratic B.O.D. results, where the carbonaceous B.O.D. actually was following a fairly regular pattern, but the oxygen used by nitrification was highly erratic.

In Table IV, as an example, are given actual observations in one series where highly variable incidence of nitrification was observed. Figure 1 shows

TABLE III.—Frequency of Onset of Nitrite Formation at Various Incubation Times in Raw Sewage B.O.D. Determinations (Total of 45 Samples)

	Days Incubated									
	1	2	3	4	5	6	7	8	9	10
Number showing nitrite formation	1	1	2	3	4	5	6	9	12	19
Per cent showing nitrite formation	2.2	2.2	4.4	6.7	8.9	11.1	13.3	20.0	26.6	42.2

TABLE IV.—Illustration of the Correction of Observed Erratic B.O.D. Values by Nitrification Equivalents to Obtain a Normal Carbonaceous B.O.D. Series

Days	D.O. Observations[1]		NO_2 Observations[1]		D.O. Corrected to[2] Base Nitrite Value		Total Obs. B.O.D.	Carbonaceous B.O.D.
	A	*B*	*A*	*B*	*A*	*B*		
1	6.96	7.00	0.03	0.030	7.05	7.09	0.90	0.81
2	6.60	6.65	0.075	0.002	6.84	6.65	1.25	1.13
3	5.56	5.43	0.165	0.195	6.11	6.08	2.38	1.78
4	5.69	5.09	0.024	0.200	5.76	5.76	2.49	2.12
5	4.93	3.15	0.088	0.620	5.21	5.26	2.95	2.64
6	5.42	5.43	0.008	0.005	5.43	5.43	2.49	2.45
7	3.18	5.34	0.200	0.042	3.85[3]	5.47	3.62	2.41
8	2.70	5.30	0.410	0.030	4.57	5.39	3.88	2.49
9	3.32	5.30	0.620	0.017	5.43	5.34	3.57	2.49
10	3.80	5.22	0.360	0.015	5.01	5.26	3.37	2.74

[1] 0-Day NO_2 = 0.004; 0-Day D.O. Observations = 7.88.
[2] The nitrite increment, calculated as oxygen, was added to the apparent D.O.
[3] Nitrate formation suspected. Not used in calculation of carbonaceous B.O.D.

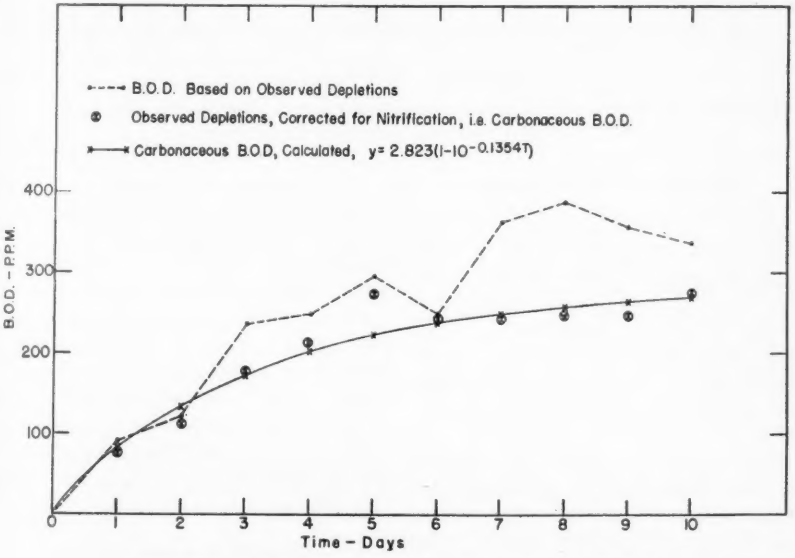

FIGURE 1.—Effect of eccentric nitrification on B.O.D.

these data plotted. It may be noted from the figure (B.O.D. based on observed depletions) that there was no apparent order in the total B.O.D. because of eccentric nitrification. This figure demonstrates that when corrections were made for erratic nitrification the carbonaceous matter was being oxidized in an orderly pattern.

Table IV shows that many observations, where duplicate portions showed highly different depletions, became very similar if the D.O. used by carbonaceous oxidation is separated from the gross depletion figure by correction for the oxygen used by nitrification.

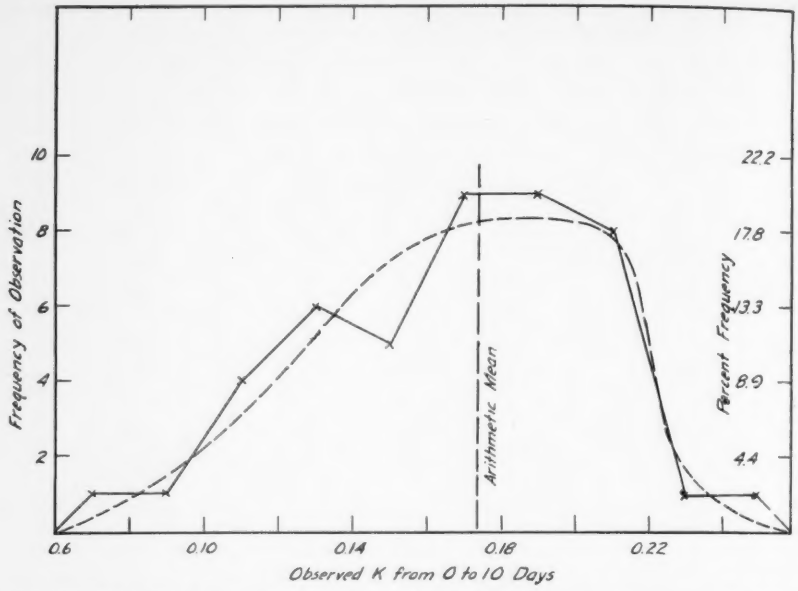

FIGURE 2.—Frequency of observed k values for 45 series of raw sewage B.O.D. determinations when corrected for nitrite formation.

Distribution of k Values

It is interesting to compare the results of the application of the Thomas slope derivation to raw sewage dilution B.O.D. data with and without correction for nitrite formation. In the work previously reported (1), 64 series of B.O.D. data with observations from 1 to 10 days were obtained by the ordinary gross B.O.D. procedure.

When the slope method was applied to these data, positive k values were obtained for 48 series. The values ranged from 0.04 to 0.29 with a mean of about 0.15. The other 16 gross B.O.D. series, however, gave negative values, indicating that the data did not fit the unimolecular reaction.

In the present study data for 45 series have been collected after correction for nitrite formation, and positive k values were obtained on all of them. The range in k values in the present study was from 0.077 to 0.25 with a mean of about 0.17.

The frequency diagram for these k values is given in Figure 2 and shows a skew pattern with the largest percentage of values occurring between 0.16 and 0.20. This distribution pattern should be considered only as representative of the k values for carbonaceous oxidation on this series of sewages. Only similar studies of other sewages can indicate whether or not it is a common distribution pattern for the k values of carbonaceous oxidation in raw sewage dilutions.

Change in k with Period of Observation

On 13 series of B.O.D. data with daily observations from 1 to 10 days, the k was derived for two periods. For inclusion in this study only series having a depletion of 2.0 p.p.m. or more in the interval between 1 and 10 days were taken. The data for 0 to 10 days were used for deriving the first k, as is common practice. For the

TABLE V.—Comparison of k and L Values for 0- to 10-Day and 1- to 10-Day B.O.D. Observations Corrected for Nitrite Formation[1] (Cincinnati Station Sewage)

Date of Sample	Dilution Water	$k_{(0-10)}$	$k_{(1-10)}$	$L_{(0-10)}$	$L_{(1-10)}$
9/30/46	T-N	0.220	0.172	575	591
9/30/46	T-N	0.212	0.153	569	589
10/21/46	T-N	0.190[2]	0.202[3]	340[2]	337[3]
10/30/46	T-N	0.120	0.107	328	336
10/30/46	Bicarb.	0.125	0.143	314	305
11/25/46	T-N	0.186	0.153	699	716
11/25/46	Bicarb.	0.154	0.154	731	723
12/9/46 (A.M.)	T-N	0.169	0.144	457	468
12/9/46 (P.M.)	C	0.214	0.157	467	479
12/10/46	C	0.221	0.149	550	585
1/29/47	C	0.145	0.080	408	464
3/25/47	C	0.171	0.125	433	454
Average	—	0.177	0.145	—	—

[1] Only data in which 1- to 10-day depletions were 2.0 p.p.m. or more were included.
[2] 0 to 8 days. [3] 1 to 8 days.

second derivation only the data from the first to the tenth day were used.

The results are given in Table V. These data show that generally the first k values obtained on data starting at 0 time are highest. The mean k for the 0- to 10-day observations is 0.177, compared to 0.145 for the 1- to 10-day observations. Such a reduction in k, with a resultant increase in L with the application of the derivation to data covering later observation periods, might suggest similar changes for k values on stream samples. Where older pollution was encountered in streams, the k for true carbonaceous oxidation may approach and fall below 0.1.

In Table VI the results on k and L derivations obtained on data for three observation periods for the same sewage are given. Besides the periods used in Table V, a third period of observation which varied from 4 to 31 hours after the start of the incubation was included on 5 and 10 per cent concentrations of sewage. For the short observation period the observation interval was 1 or 2 hours.

It will be noticed that the derivation for data on higher concentrations for shorter intervals during the first and second day results in very much higher k values and lower L values on all samples. These data suggest again

TABLE VI.—Comparison of k and L Values for Carbonaceous B.O.D. for Three Periods of Observation

Sewage	Period of Observation	Observation Interval	Sewage Concentr. (%)	k	L	Equation
A	4–14 hr.	2 hr.	5	1.428	191	$Y=33+158(1-10^{-1.43(t-1/6)})$
A	0–10 days	1 day	1	0.2505	326	$Y=326(1-10^{-0.251t})$
A	1–10 days	1 day	1	0.1525	343	$Y=162+181(1-10^{-0.153(t-1)})$
B	4–20 hr.	2 hr.	5	0.4188	272	$Y=31.2+241(1-10^{-0.419(t-1/6)})$
B	0–10 days	1 day	1	0.1885	293	$Y=293(1-10^{-0.189t})$
B	1–10 days	1 day	1	0.0966	328	$Y=127+201(1-10^{-0.097(t-1)})$
C	9–31 hr.	1 hr.	10[1]	2.306	524	$Y=66+458(1-10^{-2.31(t-9/24)})$
C	0–8 days	1 day	0.5	0.1646	898	$Y=898(1-10^{-0.165t})$
C	1–8 days	1 day	0.5	0.1043	1001	$Y=330+671(1-10^{-0.104(t-1)})$

[1] Multiple reaerations required.

that the values of k and L obtained in a series of observations is dependent to a large extent upon the concentration and period of observation selected for study.

Discussion

The results of these studies are important for understanding and interpreting all B.O.D. data. It was pointed out by Butterfield et al (3) years ago that the complexity of the microflora and fauna influenced the rate and extent of the B.O.D. reaction. It has been generally accepted, however, that the seed obtained from domestic sewage was sufficiently complex and uniform to assure uniform rates of oxidation following a short lag period at a given pH and a constant temperature.

These data show that such is not the case. In the normal pH range and at 20° C. the course of carbonaceous oxidation of sewage dilutions may be approximated by the conventional unimolecular representation, but the velocity constant varies and is decidedly not uniformly 0.1. The rate seems to be somewhat dependent upon the concentration of sewage or nutrients present, and upon the period in the course of the reactions that is selected for study.

Other factors, besides pH and temperature, which have been known to affect the rate of the reaction include the numbers of bacteria (Butterfield and Wattie) (4), solid surface (Zobell) (5), toxic organic chemicals or inorganic ions such as copper (6). Consequently the relative stability formula with the k of 0.1 should be used with the knowledge that it is a common approximation of the rate of this reaction, but that the real rate may actually vary considerably in many cases.

It is natural that the rate should vary in many streams, and also from section to section in the same stream, depending upon the combined influence of the above factors. In normal streams higher k values can be expected at points below the discharge of large quantities of domestic sewage. The k values for the oxidation rate in relatively unpolluted streams will be lower than in highly polluted streams. The Ohio River just above the Cincinnati water works intake generally has a k below 0.1, but some miles below the rate is stimulated by contributions of microflora and nutrients of Cincinnati sewage.

The question of the reliability of the 5-day B.O.D. as an exact index of pollution naturally arises as a result of these factors. At present there is no real justification for converting 5-day B.O.D. values obtained at 20° C. to L values or values for other periods of incubation on the basis of the unimolecular approximation with a k of 0.1. Since the k varies considerably, such a conversion should only be made after B.O.D. series data for a section of a stream, or a dilution of a waste or sewage, have indicated what the trend of k is under the conditions that pertain. The general use of the k of 0.1 at 20° C. for all situations is not justified and will not give proper values for such conversions.

The 5-day B.O.D. values of raw or primary effluent sewage dilutions certainly can be used as an approximate criterion of the quantity of biologically oxidizable carbonaceous organic matter if the dilutions used are held within the proper range and are not excessive. The incidence of nitrification within the 5-day period of primary sewage dilutions is apparently caused by uncontrollable variations in the sewage microflora. From our data, difficulties due to the inclusion of nitrogenous oxidation may be minimized by keeping the sewage concentrations as high as possible without depletion.

The 5-day B.O.D. of a biological treatment plant effluent may include a considerable fraction of nitrogenous oxidation, and is not strictly comparable to the 5-day value of raw or pri-

mary sewage. This has been pointed out by Theriault and others.

Recently Sawyer and Bradney (7) have proposed pasteurization followed by reseeding to eliminate nitrification within the 5-day period, and to confine the oxidation to carbonaceous materials on such effluents. The authors have considered the need for similar confinement of the 5-day B.O.D. in river samples to carbonaceous oxidation. Our experience has suggested that the majority of the ordinary river samples exhibit nitrification within the 5-day incubation period.

This is certainly true for all relatively lightly polluted streams where the 5-day B.O.D. may be 3.0 p.p.m. or less. In all such cases the unimolecular approximation does not apply to the common (uncorrected for nitrogenous oxidation) 5-day B.O.D., and application of this formula will only lead to erroneous results. Considerable work remains to be done on methods for the determination of B.O.D. in streams that will give results capable of proper interpretation.

Summary

Series of B.O.D. observations following incubation periods from 1 to 10 days were made on 45 sewage samples by a dilution technique which permitted determination and correction for nitrite formation on aliquots of portions used for oxygen utilization determinations. This technique permitted the derivation of oxidation velocity constants for strictly carbonaceous demands. It was found that when such correction was made for nitrite formation, similar k values for carbonaceous oxidation were obtained in Theriault-Nichols water, Formula C water and bicarbonate dilution water.

On five series of comparative data in two sewage concentrations from 0.4 to 1.0 per cent, higher k values were obtained in the highest concentration four times.

A table indicating the time of initiation of nitrite formation in customary sewage dilutions for 45 samples collected between September and May is presented. Dilutions of four of these samples showed nitrite formation by the fifth day and nineteen of them showed it by the tenth day.

The k values for the corrected carbonaceous demands obtained on 45 samples ranged from 0.07 to 0.25. The frequency distribution for these k values showed a skew pattern with values between 0.16 and 0.20 occurring most frequently.

Finally, data are presented which indicate that the value of k in a series of B.O.D. observations is dependent to a large extent upon the period of observation selected for study and to a lesser extent upon the sewage concentration.

The study showed that the unimolecular equation can be fitted quite satisfactorily to carbonaceous biochemical oxygen demands for any selected period of observation. Due to the flexibility of this mathematical treatment, the k and L values obtained apply only to the specific time and conditions of observation. Consequently, k and L values obtained for a short period of observation have little extrapolative value and cannot be used to estimate the expected demands for extended periods. The implication of these findings upon the interpretation of the common 5-day observations is discussed.

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RECLAMATION OF PICKLING LIQUOR WASTE

Completion of the structural framework of the new $500,000 Maneely chemical plant, being erected to convert waste materials of the Wheatland Tube and Wheatland Steel Products Companies into valuable chemicals, was recently announced.

By means of a recently developed scientific process, the new plant being erected at Wheatland, Pa., will convert waste pickling liquors into zinc sulfate, zinc chloride, zinc ammonium chloride, and pigment grade iron oxide. It is planned to offer this service to other manufacturers having similar waste problems. In accordance with present plans production is scheduled for late this year.

In conserving and reclaiming the by-products of the galvanizing processes, Maneely Chemical Company will assist in the Pennsylvania state-wide program of eliminating stream-pollution.

MECHANISM OF ACTIVATED SLUDGE PROCESS

By W. E. Abbott

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A large number of laboratory experiments of the activated sludge process on the fill-and-draw basis were made while associated with Mr. Percy Gaunt as an employee of the Shanghai Municipal Council between 1923 and 1936. Six identical small aerating devices were used to investigate the effects of one variable at a time. A mass of data resulted.

These data proved difficult to comprehend except qualitatively, and did not bear any direct relation to the operating data from large scale plants. The author was convinced that they would be easier to understand if the characteristics of each separate aeration could be expressed by a reaction constant. The rate of change of composition of aerating mixtures of activated sludge and sewage was therefore investigated.

Three conditions were found necessary to complete success:

1. The analytical method must measure only organic matter. The B.O.D. test was used at first, but proved totally unsatisfactory in the later stages owing to nitrification during incubation. Later the acid dichromate absorption test (1) (2) was used with some success. Finally the British 4-hour absorption from permanganate was adopted, nitrite being accurately estimated and allowed for.

2. Suspended matter must be excluded from samples before analysis. At first all samples were analyzed after settlement for an hour. It was soon recognized that a sharper distinction must be drawn between the suspended matter and matter in true and colloidal solution. Finally all sewages and the stronger liquids were centrifuged and the clearer liquids were filtered.

3. It must be recognized that the liquid containing the return sludge contributes to the strength of the mixed liquor at all stages. Moreover, it is improbable that this liquid changes much during aeration.

Experimental

Cylindrical vessels of about 9 liters capacity were constructed from 6-in. drain pipes. The lower portion was coned down to a Filtros diffuser. The amount of air was controlled by inserting pieces of thermometer tubing in the rubber tubing leading to the vessel from the plant air supply. Attempts were made to keep the building at as constant a temperature as possible during the test, and none of the tests involving long aeration were made when the daily fluctuations of temperature were great.

The stronger samples were centrifuged for 6 min. at 3000 r.p.m. in a Type SB-2 centrifuge after a preliminary 30-min. settlement. The clearer effluents were filtered through Postlip 633-C paper, which was the fastest that could be found.

It was not uncommon during prolonged aeration for the permanganate absorption of the filtered liquid to increase somewhat after attaining a minimum value. Frequent scrutiny of such results led to the conclusion that the agitation necessary to effect purification was causing part of the sludge particles to pass into colloidal solution as a result of friction of these particles against each other or the walls of the containing vessel. As the latter area is greater per unit volume in the laboratory tests than in plants, this effect should be greater the smaller the scale of operations. It might, in-

deed, be a reason for the notorious difficulty in correlating data from large and small scale units.

It was assumed that this "colloidal mill" effect was constant during any practical period of aeration and could be represented by the equation $E = \alpha t$ where α is a constant. This mathematical device proved successful.

Original Formulation

The data may be formulated by recourse to three equations:

$$\frac{S}{E_1} - 1 = Kt \qquad (1)$$

$$E_2 = \alpha t \qquad (2)$$

$$E = E_1 + E_2 + E_3 \qquad (3)$$

where S is the concentration of suspended matter-free sewage in the mixed liquor, E_1 is the portion of S remaining after t hours aeration, E_2 is the organic matter resulting from deflocculation for t hours, and E_3 is the absorption due to the organic matter in the added sludge substrate (assumed to be constant). K and α are constant in each case.

TABLE I.—Comparison of Observed and Calculated Results of Activated Sludge Treatment

Test No.	Hours Aeration (t)	Calculated Values of 4-Hour Oxygen Absorption (p.p.m.)				Observed 4-Hour O_2 Absorption (p.p.m.)
		E_1	E_2	E_3	$E_1+E_2+E_3$	
A[1]	3.0	71.3	0.4	4.0	75.7	76.8
	6.0	62.4	0.8	4.0	67.2	66.4
	22.5	37.1	3.2	4.0	44.3	45.2
	30.0	31.3	4.2	4.0	39.5	38.0
	47.0	23.1	6.6	4.0	33.7	34.6
B[2]	1.8	16.8	0.6	3.4	20.8	20.8
	4.1	11.6	1.4	3.4	16.4	15.7
	6.0	9.2	2.0	3.4	14.6	14.9
	22.0	3.4	7.3	3.4	14.1	14.0

[1] Test made at 20° C. with 1500 p.p.m. return sludge solids and 0.25 liter per min. of air. Calculated from $\frac{83.0}{E_1} = 1 + 0.055t$; $E_2 = 0.14t$; $E_3 = 4.0$.

[2] Test made at 17° C. with 2200 p.p.m. return sludge solids and 0.266 liter per min. of air Calculated from $\frac{25.8}{E_1} = 1 + 0.3t$; $E_2 = 0.33t$; $E_3 = 3.4$.

Table I gives two examples. In example A the absorption of the suspended matter-free sewage and sludge liquor was 110.6 p.p.m. and 16.0 p.p.m., respectively. Since 6 liters of sewage were mixed with 2 liters of sludge, the values of S and E_3 were $110.6 \times 6/8$ or 83.0 p.p.m. and $16.0 \times 2/8$ or 4.0 p.p.m., respectively. K was taken as 0.055 and α as 0.14. In example B the values of S, E_3, K and α were 25.8, 3.4, 0.30 and 0.33 p.p.m., respectively.

It would appear from a study of the data that K tends to increase with increasing mixed liquor solids, provided aeration is sufficient. The value α shows a tendency to increase with the degree of agitation. The effect represented by equation (2) will normally be negligible over the short periods found in practice.

Rearranging the symbols in equation (1), it becomes

$$\frac{S - E}{E} = Kt \qquad (4)$$

or, in words,

$$\frac{\text{Soluble matter removed}}{\text{Soluble matter remaining}} = \text{Constant} \times \text{Time}$$

Alternative Formulation

Derivation of the three-equation formulation outlined above is time consuming. Re-examination of the base data led to the production of a single equation which represented the facts practically as well, although it had no apparent relationship. Using the symbols as defined above this equation has the form:

$$\text{Log}\,\frac{S + E_3 - F}{E - F} = \lambda t \qquad (5)$$

The additional symbol F is approximately the minimum value of E at-

tained during aeration. The factor λ is a constant in each case. This equation has the great advantage of possessing only one coefficient. On the other hand it fails completely to represent the later stages of aeration when there is a tendency for the value of E to increase. While rather cumbrous in the above form, examination shows that in effect $(S + E_3 - F)$ is the total organic matter removed down to the point of maximum purification while $(E - F)$ is the residual organic matter capable of being removed after t hours.

In words the equation becomes

$$\text{Log} \frac{\text{Total removable matter}}{\text{Residual removable matter}} = \text{Constant} \times \text{Time}$$

It is interesting to note that this equation is monomolecular in form.

Table II shows the application of equation (5) to the same data as in Table I. In example A the value of F is taken from the absorption-time graph as 33.0. Therefore $S + E_3 - F = 83.0 + 4.0 - 33.0 = 54.0$. In equation B, S is calculated from the absorption of the centrifuged sewage as 25.8. Then $S + E_3 - F = 25.8 + 3.4 - 14.0 = 15.2$.

TABLE II.—Application of Equation (5) to Data of Table I

Test No.	Hours Aeration (t)	4-Hour Oxygen Absorption (p.p.m.)		
		$E-F$ (calc.)	E (calc.)	E (obs.)
A[1]	3.0	42.7	75.7	76.8
	6.0	33.8	66.8	66.4
	22.5	9.3	42.3	45.2
	30.0	5.2	38.2	38.0
	47.0	1.4	34.4	34.6
B[2]	1.8	6.1	20.1	20.8
	4.1	1.9	15.9	15.7
	6.0	0.7	14.7	14.9
	22.0	0.0	14.0	14.0

[1] Calculated from $\text{Log} \frac{54.0}{E - 33.0} = 0.034t$.

[2] Calculated from $\text{Log} \frac{15.2}{E - 14.0} = 0.22t$.

Values of λ have been worked out for all cases wherein the number and timing of observations permitted. These results are particularly interesting when several simultaneous tests with the same sewage and sludge samples provided values of λ (Table III). It should perhaps be mentioned at this point that mixtures differing only in the quantity of activated sludge were produced by adding equal volumes of sewage to different volumes of sludge, and bringing all mixtures up to the maximum volume by addition of effluent.

Inspection shows that the values of λ vary in quite a regular and logical manner. Other factors remaining equal, λ tends to be inversely proportional to the numerator in equation (5). It also tends to increase with the quantity of air. When the quantity of sludge is increased while other factors remain constant the value of λ first increases and then decreases.

It was discovered that the effect of sludge quantity on λ in any group of simultaneous tests could be explained on the assumption that each unit of sludge required a certain amount of air for its mere maintenance. The assumption was made, for instance, that the sludge sample used in simultaneous tests Nos. 1 to 4 in Table III required for its maintenance 0.072 liters of air per min. per 1000 p.p.m. of mixed liquor solids. The difference between the actual quantity of air and this calculated quantity is described as "effective air" in Table III. Similarly, the assumption that the sludge sample used in tests Nos. 5 to 9 in Table III required 0.062 liters per min. for its maintenance made it readily possible to calculate the values of λ.

In most series of tests the value of λ could be calculated on the assumption that it was directly proportional to the quantity of sludge and the "effective air" as above defined, and

TABLE III.—Determination of λ in Simultaneous Tests[1]

Test No.	Mixed Liquor Solids (p.p.m.)	Applied Air (liters per min.)		$S+E_3-F$	F	λ	
		Actual	"Effective"			Derived from Data	Calculated[2]
1	550	0.143	0.103	16.2	13	0.05	0.05
2	550	0.217	0.177	15.2	14	0.09	0.09
3	1100	0.253	0.173	15.2	14	0.18	0.18
4	2200	0.267	0.107	15.2	14	0.22	0.22
5	1600	0.243	0.144	35.0	18	0.13	0.13
6	2200	0.223	0.087	35.0	18	0.12	0.11
7	2200	0.227	0.091	34.0	19	0.12	0.12
8	2700	0.240	0.073	34.0	19	0.11	0.12
9	3600	0.240	0.017	33.0	20	0.05	0.04

[1] Tests Nos. 1 to 4, incl., were made simultaneously at 20° C.; tests Nos. 5 to 9, incl., made simultaneously at 12° C.

[2] Equation (6) used for calculating tests Nos. 1 to 4, incl.; equation (7) used on data of tests Nos. 5 to 9, incl.

inversely proportional to the entity $(S + E_3 - F)$, or the maximum reduction in strength of the mixed liquor. The values of λ in the last column of Table III are derived from

$$\lambda = \frac{\text{sludge in p.p.m.} \times \text{"effective air"}}{70 \times (S + E_3 - F)} \quad (6)$$

for tests Nos. 1 to 4, and

$$\lambda = \frac{\text{sludge in p.p.m.} \times \text{"effective air"}}{50 \times (S + E_3 - F)} \quad (7)$$

for tests Nos. 5 to 9.

Discussion

The findings apply to tests on fundamentally domestic sewages in quantities just under 10 liters. It is impossible to attempt to apply the equations to the results of other workers, as none have made the necessary degree of distinction between suspended and other matter.

Much experimental work was done on the effect of time and speed of centrifuging on the 4-hour absorption of sewages and badly clarified mixed liquor samples. The effect of the type of paper and other conditions on the filtrate from clarified mixed liquor samples was also investigated. It suffices for the purposes of this paper to say that filtrates from the passage of limited volumes through Postlip 633-C paper had nearly the same composition as when the suspended matter was removed by centrifuging under the conditions stated above.

Summary

Two apparently unrelated methods have been evolved of formulating the rate of change of the organic matter in true and colloidal solution when sewage is aerated with activated sludge. The first involves, *inter alia*, the assumption that a certain degree of deflocculation occurs through friction of the gelatinous sludge particles against each other or the walls of the aerator. This formulation is cumbrous and difficult to derive. The second is a single equation, monomolecular in type and with a single coefficient, which in effect measures the rate of decrease of that portion of the analytical constituent capable of removal under the conditions of the test.

There is no question that the monomolecular formulation is more convenient since only one coefficient is involved. In a simultaneous series of tests with the same sewage and sludge

samples, the value of this coefficient varies in a regular manner with the conditions. It has proved convenient to divide the air supply into a portion necessary to merely maintain the sludge and a portion free to provide the necessary slight excess for the activated sludge action.

References

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A NOTE ON THE DETERMINATION OF VOLATILE ACIDS IN DIGESTING SLUDGES

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It has been reported that some workers have had difficulty in applying the modified duClaux test for volatile acids as described in Appendix I (Non-Standard Methods), p. 218 of the Ninth Edition of Standard Methods for the Examination of Water and Sewage. The error which appears to be due to high results has been traced to a "carry-over" of H_2SO_4 in two laboratories. To avoid "carry-over" the volume of the flask should be at least twice the original volume of liquid. A "Claissen" flask is preferred in this laboratory.

It is also regretted that the directions fail to state that the test is intended to be applied to settled overflow liquor. Any considerable amount of coarse organic solids may increase foaming and may be attacked by the sulfuric acid giving volatile products.

ALTERNATING TWO-STAGE FILTRATION OF SEWAGE AND MILK WASTE*

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The sewage treatment plant at Marysville, Ohio, dates back many years. It originally consisted of a bar screen, diversion chamber, Imhoff tanks, and four stone contact filters followed by sand filters. This plant treated the waste from a population of approximately 4,000 persons with the industrial waste of a milk processing plant and one other minor manufacturing plant.

It later became necessary to remodel and enlarge the sewage treatment plant to obtain a higher degree of efficiency because the receiving stream is tributary to the Columbus, Ohio, water supply. The remodeled plant was designed to handle a maximum flow of 1.0 m.g.d., or the waste of a predicted population of 7,500 persons.

Plant Description

The two Imhoff tanks were converted to separate primary sedimentation tanks with a detention period at maximum design flow of 2 hours.

The four contact filters were equipped with Yeomans rotary distributors, the filter control building being located in the center of the four units (Figure 1). Two wet wells were provided—one to receive the settled effluent for pumping to the first pair of filters, the other to receive the effluent from the first pair of filters before pumping it to the second pair of filters. The capacity of the two wet wells,

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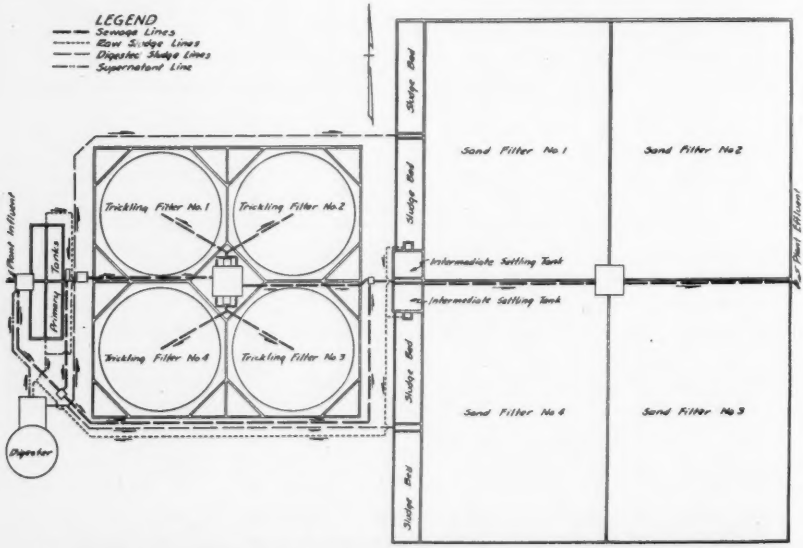

FIGURE 1.—Flow sheet of Marysville, Ohio, sewage treatment plant.

when the filters are operated in parallel, is 5,000 gal. and their capacity when operated in series is 2,850 gallons.

The filters are dosed by four centrifugal pumps of 350 g.p.m. capacity each. The discharge lines of the center column of the distributors have been provided with surge lines to prevent the loss of mercury at the seals.

The pumps, piping and valves are arranged so that ample flexibility of operation is provided. The settled sewage may be treated in either of two ways by these filters, namely, series or parallel operation. The sequence of dosing, when operated in series, may be alternated. With parallel operation this settled sewage receives a single passage through the stone filters, whereas series operation provides two passages or double filtration. The pumps are controlled by floatless controls which operate with electrodes and relays.

The four trickling filters are each 90 ft. in diameter and are equipped with individual rotary distributors, affording uniform distribution on each bed. The total stone depth is approximately 5½ feet.

Marysville has a population of 4,037 persons (1940 census), with 600 persons at the Marysville Reformatory also connected to the sewer system. Approximately 4,300 persons are served. The industrial waste of the Nestle's Milk Processing Plant is treated with the sanitary waste.

Two-Stage Filtration

The writer has presented data at a previous conference concerning the feasibility of treating milk waste by two-stage filtration. Results achieved were found to be satisfactory. The valves and pumping equipment were so installed at the Marysville plant that the sequence of dosing on the filters could be changed as desired. Mr. G. A. Hall of the State Department of Health requested that data be compiled which would indicate whether any benefits would be derived from changing the sequence of dosing or whether it would be better to operate without alternation.

The filters had been in operation for a long period of time with no change in the dosing sequence, and samples were collected and analyzed. The dosing sequence was then changed

TABLE I.—Comparison of Results of Various Methods of Trickling Filter Operation at Marysville, Ohio

Operating Data	Method of Operation		
	Single-Stage	Two-Stage; Dosing Sequence Unchanged	Two-Stage; Dosing Sequence Changed
Ave. sewage flow (m.g.d.)	0.695	0.693	0.669
5-Day B.O.D. (p.p.m.):			
Applied (settled) sewage	312	378	329
First-stage effluent	82	177	84
Second-stage effluent	—	78	59
B.O.D. Applied (lb. per cu.yd. media):			
First stage	0.407	0.984	0.818
Second stage	—	0.461	0.208
B.O.D. Removal (lb. per cu.yd. media):			
First stage	0.300	0.523	0.610
Second stage	—	0.268	0.078
Efficiency (%):			
First stage	73.7	53.2	73.8
Second stage	—	58.1	32.1
Both stages	—	79.4	81.6

every few days and samples again were collected and analyzed. Data were later obtained to indicate the results when operating as single stage filters. A summary of the results is presented in Table I for comparison of efficiencies.

Results

During the periods of single stage operation, an average flow of 695,000 gal. of settled sewage was applied on four filters. The B.O.D. load applied was 0.407 lb. per cu. yd. of media, and 0.300 lb. of B.O.D. per cu. yd. of media were removed. The efficiency of the filters was 73.7 per cent.

Two-Stage Filtration Without Change in Dosing Sequence

An average flow of 693,000 gal. of settled sewage was applied on the first stage of operation and again on the second stage. The average B.O.D. load applied on the first stage was 0.98 lb. per cu. yd. of media and the average B.O.D. applied on the second stage was 0.46 lb. per cu. yd. The average B.O.D. removal was 0.52 lb. and 0.27 lb. per cu. yd. of media, respectively. The efficiency of operation of each stage was about equal, being slightly higher in the second stage. The over-all efficiency of both stages was 79.4 per cent.

Two-Stage Filtration with Periodic Change in Dosing Sequence

An average flow of 669,000 gal. of settled sewage was applied on the first stage of operation and again on the second stage. The average B.O.D. load applied on the first stage was 0.82 lb. per cu. yd. of media, and the average B.O.D. applied on the second stage was 0.21 lb. per cu. yd. The average B.O.D. removals were 0.61 lb. and 0.08 lb. per cu. yd. of media, respectively. The efficiency of operation of the first stage was more than twice that of the second stage. The over-all efficiency of both stages was 81.6 per cent.

Discussion

Two-stage filtration without a change of dosing sequence resulted in a heavier and darker colored growth on the primary filter media than that on the secondary filter. Two-stage filtration with no change in dosing sequence produced the greatest filter efficiency in the second stage, whereas with a periodic change in dosing sequence, the greatest efficiency was achieved on the primary filters.

With no change in dosing sequence, the dissolved oxygen content of the primary filters (first stage) was almost negligible, whereas when changing dosing sequence the dissolved oxygen content of the primary filter effluent was greater than 1.0 p.p.m. The second stage filter effluent had a satisfactory dissolved oxygen content in both instances.

Very little can be said concerning suspended solids, as a heavy slough is usually encountered at all times in treating milk waste by this method, but it was found that the sloughing of solids was increased as the dosing sequence was changed.

Single-stage filtration produced a satisfactory effluent with a small amount of dissolved oxygen, but the efficiency of the filters was 5.7 per cent less than for two-stage operation without a change of dosing sequence, and 7.9 per cent less than that when two-stage operation with a change of dosing sequence was used.

The treatment of milk wastes by two-stage filtration is an effective method of B.O.D. removal, being slightly more effective when the dosing sequence is periodically reversed. There is apparently some benefit derived in the control of ponding, and a decrease in psychoda flies was noticeable when the dosing sequence was alternated.

Industrial Wastes

TREATMENT AND DISPOSAL OF WASTE SOLUBLE OILS

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There are a large number of different soluble oils offered on the commercial market, each having a somewhat different composition. In general it can be said that the soluble oils are homogeneous compositions containing mineral oil, pine oil, or other hydrocarbon oils; emulsifying agents such as potassium or sodium soaps or sulfonated oils, and an indeterminate amount of water. The general appearance is that of a pure oil, but when mixed with water a very fine, stable, milky emulsion is formed.

This soluble oil emulsion is widely used in the manufacturing field whereever machining operations are performed. It is circulated over the metal parts during machining and acts both as a coolant and as a lubricant. The dilution of the soluble oil in water will depend upon the particular type of machining operations and will vary between 1 to 10 and 1 to 100. The average and perhaps most used dilution is about 1 to 20. Pure water has the best heat absorbing qualities of the liquids readily adaptable for the cooling operation, but cannot be used without the emulsified oil as it tends to cause corrosion and, furthermore, does not possess lubricating qualities.

In the larger shops the soluble oil emulsion may be contained in a central distribution system and used many times before disposal. In instances where the machines are widely scattered over the factory, or where the factory is relatively small, each machine has its own individual cooling system and the emulsion generally goes directly to the drain after it has been used only once. In either case, however, it must eventually be disposed of since through continued re-use it picks up a large quantity of foreign material which, after reaching a certain concentration, adversely affects the machining operations. Also, as time elapses, the oil becomes rancid due to the development of a bacterial growth, and may cause corrosion of the metal parts and skin disease on the machine operator. The life of the coolant when used in central systems can be increased by the use of purification equipment such as gravity settling tanks, centrifuges and filters to remove the foreign material; and the addition of disinfectants to retard bacterial growth.

The quantity of coolant to be disposed of will vary with the size of the factory and the nature of the machining operations. In a large factory several hundred thousand gallons may be discharged into the drains each month. It is recognized that the soluble oil disposal problem is not the major contributing factor of the industrial oil pollution problem, but it is one of the contributing factors.

Purpose of Study

The purpose of this study was to find a method of breaking the oil-in-water emulsion so that a major portion of the oil can be recovered, and also to find ways and means of treating the residual liquid for the removal of

the remaining oil and B.O.D. Several factors were controlling in this study. First, the method should be simple and inexpensive; second, it seemed desirable to recover the oil in such a condition that it can be used; and third, the final effluent from the process should have an oil content below that regarded as undesirable in the receiving stream and should not have a high B.O.D.

Soluble oil in waste waters is undesirable for several reasons. If the drain discharges directly to a lake or river, the emulsion will eventually break and the oil will coat the surface of the water. This prevents the reaeration of the water, spoils the value of the waterway as a recreational site, and in general creates a public nuisance. If the drain discharges into a municipal sewage treatment plant, it will upset the normal working conditions of the plant. According to L. F. Oeming, Sanitary Engineer for the Michigan Stream Control Commission, acceptable limits of oil concentration in waste waters have not been established, but in the majority of cases in Michigan waters, effluents containing not more than 15 p.p.m. are considered satisfactory. If the waste enters a municipal sewage plant the limit may be increased somewhat because the dilution of the waste with sewage reduces the concentration, but for satisfactory plant operation the oil concentration should be kept below 15 p.p.m.

Some preliminary observations indicated that it is desirable to divide the treatment process into two steps, namely, breaking the emulsion for the recovery of oil and the removal of the residual oil and B.O.D. Hart in "Industrial Waste Disposal for Petroleum Refineries and Allied Plants" also indicates that such a procedure is the most practical and economical method. Several difficulties were encountered when an effort was made both to precipitate the oil and to remove it as a sludge in one step. The relatively high oil content in the original waste caused a portion of the sludge containing oil to float. The presence of the flocculated chemicals in the oil layer definitely decreased its value for further use. That portion of the sludge that settled was very sticky and difficult to remove from the settling tank. These difficulties were eliminated by breaking the emulsion with calcium chloride and recovering the major portion of the oil, and then, by the addition of flocculating agents, removing the residual oil and B.O.D.

Experimental Procedure

Synthetic soluble oil wastes were used for this study since it seemed desirable to compare a number of typical oils. The oils were obtained from several oil companies which supply manufacturing concerns in this area. These were diluted to make 1 to 20 oil-in-water emulsions, which were treated with several chemicals in the manner described below in order to determine which chemical was most desirable to break the emulsion without damage to the recovered oil.

The emulsions were placed in a series of containers equipped with a mixing device. Varying quantities of the chemical were added and the mixture stirred rapidly for 10 minutes. Later it was found that the oil separated faster if a slow rate of stirring was continued over the 30-min. period. At the end of this time a 100-ml. sample of the lower water layer was drawn off and tested for oil. In order to calculate the percentage removal of the oil a 100-ml. sample of the original emulsion was also tested for oil. The results are tabulated in Table I and will be discussed later.

After it was found that calcium chloride gave the best break and the cleanest oil, one of the samples was selected for a further study of the second step in the process. A quantity of

TABLE I.—Use of Calcium Chloride and Ferrous Sulfate to Break Emulsion

Soluble Oil No.	Dilution, Oil to Water	Chemical Used	Quantity Added (gm./l.)	Initial Oil Content (p.p.m.)	Oil in Water Layer (p.p.m.)	Removal (%)	Initial B.O.D. (p.p.m.)	Final B.O.D. (p.p.m.)	Reduction B.O.D. (%)	Oil Layer Condition
			1.2		37,373	5.0				
			1.8		632	98.4				
1	1–20	$CaCl_2$	2.4	39,324	470	98.8	7,652	180	97.7	Clean
			3.0		367	99.1				
			1.8		64,314	15.0				
1	1–10	$CaCl_2$	2.4	75,500	1,233	98.4	—	—	—	Clean
			3.6		896	98.8				
			1.2		3,563	91.0				
2	1–20	$CaCl_2$	1.8	38,940	603	98.5	3,975	750	81.0	Clean
			2.4		794	98.0				
			1.2		20,897	43.5				
3	1–20	$CaCl_2$	1.8	36,983	617	98.3	11,175	1530	86.3	Dirty
			2.4		667	98.2				
			1.2		33,464	6.5				
4	1–20	$CaCl_2$	1.8	35,896	301	99.2	1,300	147	88.7	Clean
			2.4		115	99.7				
			1.8		43,454	4.2				
5	1–20	$CaCl_2$	2.4	45,278	1,089	97.6	12,100	1680	86.1	Clean
			3.0		209	99.5				
			4.3		1,189	96.9				
1	1–20	$FeSO_4$	5.4	38,029	745	98.0	—	—	—	Dirty
			6.5		979	97.5				

a 1 to 20 dilution of oil No. 1 was made up and treated with calcium chloride. The mixture was flash mixed and then very slowly stirred for 30 min. in order to build up the oil particles which collected as a layer on the surface. At this time the water layer was drawn off and portions measured into several containers. A 100-ml. sample of this water layer was then tested for oil. Several chemicals were selected as coagulants. These chemicals were added to the several portions and the mixture flash mixed, coagulated for 20 min. and then permitted to settle for one hour. The liquor above the sludge was then tested for oil. The results obtained will be discussed later.

Oil Test

It would probably be more correct to call this a test for the petroleum ether soluble constituents, but for reasons of simplicity the organic oils and vegetable fats extracted along with the oil will be referred to as "oil." The test for oil was made by solvent extraction with petroleum ether. Before it is possible to extract the oil from an oil-in-water emulsion it is first necessary to break the emulsion. This was accomplished by adding 2 ml. of 2N calcium chloride per 100 ml. of sample. The oil extraction was then made in a separatory funnel with 10-ml. portions of petroleum ether. The number of extractions necessary will depend upon the quantity of oil present. In testing for oil in the water layer after the emulsion had been broken it was deemed advisable to add an additional 1 ml. of 2N calcium chloride per 100 ml. of sample, to insure complete destruction of the emulsion and allow

for the complete extraction of the remaining oil. The water layer was drawn off the bottom of the separatory funnel and the ether layer poured into a weighed beaker. The solvent was evaporated on a steam bath and the water removed in a 103° C. drying oven, then the remaining oil residue was weighed. Portions of 100 ml. were used in all cases except for the final liquid from complete treatment. In the latter case 400-ml. portions were evaporated to about 100 ml. prior to extraction of the oil.

Study of First Step

It was not considered necessary to test all of the many grades of soluble oils on the market since it was expected that they would react in much the same manner as the five typical oils studied. In the course of the study several chemicals were eliminated as agents for breaking the soluble oil emulsion. Sodium chloride was used, but excessive quantities were required for effective treatment and the break was not complete. Lime treatment was also attempted but this formed a thick sticky precipitate that would have been very difficult to handle and would have created another disposal problem. Tables I and II give the more pertinent information gathered in the study of the first step of this treatment procedure. These data show the results obtained from the use of calcium chloride, ferrous sulfate and sulfuric acid.

From Tables I, II, and III it is evident that calcium chloride may be the answer to the problem of breaking the oil-in-water emulsion. It is not claimed that calcium chloride will serve the purpose in all cases, but the results show that it was effective with the five oils treated during this study.

While gathering these data it was indicated by a number of sources that the emulsion could easily be broken by acid treatment. From Table II it can be seen that even though the acid does break the emulsion, large quantities are required and, furthermore, a very acid water layer must be disposed of. Calcium chloride on the other hand is inexpensive, small quantities are required, it can be easily handled, it forms no sludge, and does not create

TABLE II.—Use of Sulfuric Acid to Break Emulsion

Soluble Oil No.	Dilution, Oil to Water	Quantity Acid Added (gm./l.)	Initial Oil Content (p.p.m.)	Oil in Water Layer (p.p.m.)	Removal (%)	pH of Water Layer	Oil Layer Condition
1	1–20	22.1	39,324	10,304	74.0	0.7	Clean
		25.8		3,462	91.0	0.6	
		29.4		1,989	95.0	0.6	
2	1–20	25.8	38,940	762	98.0	0.5	Clean
		29.4		619	98.4	0.4	
		33.1		500	98.7	0.3	
3	1–20	22.1	36,983	4,562	87.6	0.8	Clean
		25.8		2,042	94.5	0.7	
		29.4		1,804	95.1	0.6	
4	1–20	22.1	35,896	3,691	89.5	0.6	Clean
		25.8		278	99.2	0.5	
		29.4		273	99.4	0.5	
5	1–20	22.1	45,278	1,194	97.6	0.6	Dirty
		25.8		502	98.9	0.6	
		29.4		417	99.1	0.5	

TABLE III.—Comparison of Results

Soluble Oil No.	Dilution	Chemical Added (gm./l.)	Initial Oil Content (p.p.m.)	Final Oil Content (p.p.m.)	Removal (%)	Chemical Reqd. (lb./1000 gal.)	Oil Layer Condition
1	1–20	1.8 CaCl	39,324	632	98.4	15	Clean
		5.4 $FeSO_4$	38,029	745	98.0	45	Dirty
		29.4 H_2SO_4	39,324	1989	95.0	245	Clean
2	1–20	1.8 CaCl	38,940	603	98.5	15	Clean
		29.4 H_2SO_4	38,940	619	98.1	245	Clean
3	1–20	1.8 CaCl	36,983	615	98.3	15	Dirty
		29.4 H_2SO_4	36,983	1804	95.1	245	Clean
4	1–20	1.8 CaCl	35,896	301	99.2	15	Clean
		25.8 H_2SO_4	35,896	278	99.2	215	Clean
5	1–20	3.0 CaCl	45,278	209	99.5	25	Clean
		25.8 H_2SO_4	45,278	502	98.9	215	Dirty

another disposal problem. In a 1 to 20 dilution of soluble oil it is possible to attain a 98.4 per cent removal of oil with 15 lb. of calcium chloride per 1000 gal. of emulsion. With acid treatment of an equal volume, it would require 245 lb. of sulfuric acid (conc.) to obtain a 95 per cent removal of oil.

Calcium chloride gave results superior to ferrous sulfate since it not only required a smaller quantity, but also the oil layer was in a cleaner condition in a majority of the cases. About three times as much ferrous sulfate was required for the same degree of treatment.

The quantity of oil recovered will depend upon the concentration of the emulsion. In the case of the 1 to 20 dilution studies about 40 gal. of oil will be recovered from 1000 gallons. Higher dilutions require somewhat less calcium chloride and the amount of oil recovered will naturally be less. The reverse is true of the lower dilutions.

The original B.O.D. varies from 1300 to 12,100 p.p.m., depending upon the soluble oil used. With calcium chloride treatment and separation of the oil this range is reduced to 147 to 1680 p.p.m. depending upon the initial B.O.D. This represents a reduction of 81 to 97 per cent.

Study of Second Step

It was expected that all the water layers from the first step would respond to treatment in a similar manner, therefore one oil was selected and treated for the further removal of oil and B.O.D. In order to clarify the water layer by flocculation and settling it was first necessary to add particles on which the floc could build. Also these particles had to be of sufficient density that they would settle after they had been flocculated and saturated with oil. Bentonite and lime were the two materials used to furnish the particles on which the floc could build. These were coagulated with ferrous sulfate, alum, and ferric sulfate. The study indicated that lime and ferric sulfate produced the best settling floc. The data obtained from the use of lime and ferric sulfate are shown in Table IV.

From the data it can be seen that 0.3 lb. of lime and 1.2 lb. of ferric sulfate per 1000 gal. will give an effluent below the 15 p.p.m. that is considered satisfactory, as discussed previously. These quantities of lime and ferric sulfate will probably not be effective

TABLE IV.—Use of Lime and Ferric Sulfate for Final Treatment; 1:20 Dilution of Oil No. 1

Lime Used (mg./l.)	Ferric Sulfate Used (mg./l.)	Initial Oil Content (p.p.m.)	Water Layer Oil Content (p.p.m.)	Final Oil Content (p.p.m.)	Removal (%)	Initial B.O.D. (p.p.m.)	Water Layer B.O.D. (p.p.m.)	Final B.O.D. (p.p.m.)	Removal (%)	Lime Reqd. (lb./1000 gal.)	Ferric Sulfate Reqd. (lb./1000 gal.)
34.4	68.8	39,324	412	27.3	99.93	7,652	275	130	98.3	0.3	0.6
34.4	103.2	39,324	412	14.5	99.96	7,652	275	124	98.4	0.3	0.9
34.4	137.6	39,324	412	12.3	99.97	7,652	275	128	98.3	0.3	1.2
34.4	172.0	39,324	412	10.3	99.97	7,652	275	95	98.8	0.3	1.5

under all conditions, and the correct value will have to be determined in the laboratory in each instance. However, it is believed that the quantities required will not vary greatly from the above data.

The B.O.D. reduction in this step is relatively little in comparison to the initial B.O.D. of the emulsion. However, it does bring the final B.O.D. down to a range of 95 to 130 p.p.m. This represents a removal of 98.3 to 98.8 per cent of the initial B.O.D.

Possible Facilities for Full Scale Treatment

Although the results previously presented were obtained from a laboratory study and undoubtedly it is desirable to try them in a pilot plant installation, yet in this case it seemed feasible to speculate, at least, on the type of facilities required for full scale treatment.

In solving the oil problem in industry it is first necessary that all possible waste soluble oil be kept separate from other wastes, even if it is necessary to install containers when the machines are on individual cooling systems. This separation will lessen the volume of waste to be treated and will also improve the oil recovery. Oil is slightly soluble in water and the greater the quantity of water the greater the amount of oil carried out in the water media. Some soluble oil will be lost due to drag-out, which cannot be separated.

In case individual cooling systems are used on each machine the waste oil should be collected in containers and disposed of to the treatment plant periodically. The machines may be on a central system, in which case the oil is returned to pits for recirculation either with or without purification equipment. In this case also the oil will be discarded periodically. The batch process is superior to the continuous flow process for the treatment of waste oil that is discarded in this manner. The continuous flow method is adapted to the treatment of the waste oil when discharged continuously and in large volumes.

Batch Process

The equipment described below is suggested to accommodate the batch process (Figure 1). It will consist of two large hopper-bottom tanks, each equipped with a coagulating mechanism that will rotate at a speed to give a peripheral velocity of 1 f.p.s. to the larger paddle. Three small chemical tanks to hold the calcium chloride, lime, and ferric sulfate solutions are located on a platform just above the mixing tank. If steel tanks are used for the calcium chloride and ferric sulfate solutions, they must be rubber lined, since in concentrated solutions they are very corrosive. Two pump pits are located between the large mixing tanks. The first pit has a float controlled pump to lift the soluble oil to the first tank. The second pit has a manually operated pump to lift the water layer to the second mixing tank.

The size of each mixing tank should be such as to hold at least one day's flow of waste soluble oil. The maxi-

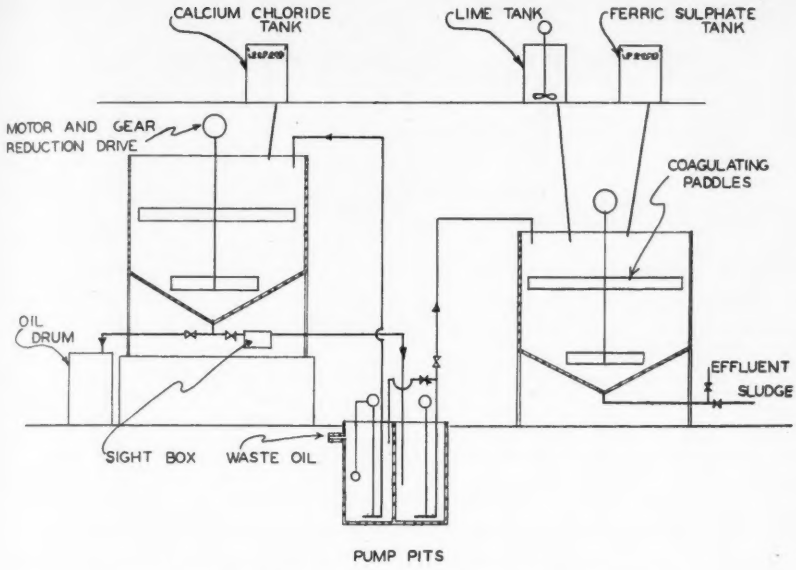

FIGURE 1.—Facilities for batch treatment of waste soluble oil.

mum strength of the chemical solutions will be limited by the solubility of the chemical in water. The strength used should be such that an easily measurable amount is added to each 1000 gal. of waste. For example, with a calcium chloride solution of 3 lb. of calcium chloride per gallon of water, 5 gal. will be required per 1000 gal. of waste.

The daily waste soluble oil is collected in the first pump pit and pumped into the first mixing tank. The waste level in the pit is controlled by the float. When the mixing tank is full the calcium chloride is added and mixed for one hour to break the emulsion and separate the oil. After separation the water layer is slowly drawn off the bottom of the tank into the second pit and pumped into the second tank. At the first sign of oil in the sight box the valve must be closed immediately. It is important that this procedure be followed very carefully in order to avoid loss of oil to the second step. The final portion of the water layer in the second pump pit should be returned to the first pump pit so as to prevent as much oil as possible from entering the secondary treatment tank. The oil in the first tank can now be drawn off into drums and recovered.

The second step involves clarification of the water layer by flocculation and settling. The calculated quantities of lime and ferric sulfate are added from the solution tanks and the coagulation mechanism operated for 20 minutes. Coagulation is discontinued and the mixture settled for one hour. The sludge is now drawn and removed to storage tanks or lagoons, and the clear liquor discharged to the drain.

Continuous Flow Process

The continuous flow process is illustrated in Figure 2. Soluble oil waste either flows or is pumped into the first mixing tank, depending upon the elevation of the tanks, and the emulsion is broken by the addition of calcium chloride. The size of the tank should be such as to hold one minute's flow of

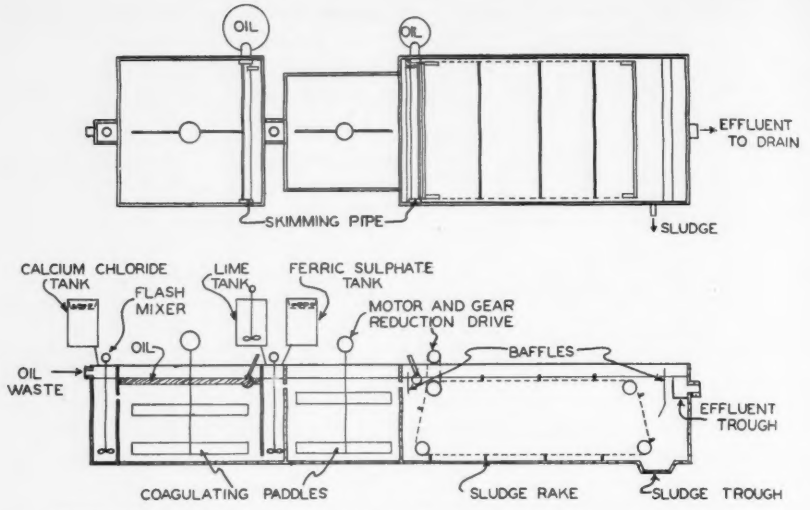

FIGURE 2.—Facilities for continuous flow treatment of waste soluble oil.

waste. Following this is the removal of the oil in the first coagulation tank where the waste is retained for a period of 30 minutes. The oil is coagulated into large drops by the paddles and rises to the surface where it is periodically or continuously removed by a slit-pipe skimming device. The paddles are motor driven through a reduction gear to rotate at a speed to give a peripheral velocity of 1 f.p.s. The slit-pipe skimming device is mounted on bearings so that it can be rotated to control the depth of oil skimmed. The oil is collected in containers and may be used for fuel after a further removal of water.

The second major step of the process is the clarification of the water layer which flows from the bottom of the first coagulation tank to the second mixing tank. Lime and ferric sulfate are added and rapidly mixed with the water by a flash mixer. This tank is the same size as the first mixing tank. Following the mixing, coagulation takes place for 20 min. in the second coagulation tank, and settling for 60 min. in the settling tank. The settling tank has a skimming and sludge removal device, effluent trough, and an influent baffle. The influent baffle prevents the short circuiting of the sludge to the effluent trough.

The device for skimming and sludge removal consists of scrapers attached to two endless chains which operate over sprockets on each side of the tank. These scrapers pull the sludge to a hopper in the bottom of the tank, from which it is removed by gravity or with a pump depending upon the elevation of the tanks. Any oil which may separate in this tank is removed to a slit-pipe skimmer by the scrapers on the return flight, and is collected in containers for use along with that obtained from the first coagulation tank. The sludge may be dried on beds, ponded or hauled to a disposal field in the wet condition.

Conclusion

The treatment of waste soluble oil is desirable even though the quantity may be small. This is a source of pollution in industry that can and should be prevented. The removal of this oil will not solve the oil pollution problem, but will decrease the concentration of oil in waste waters from industrial plants.

A PLATING WASTE DISPOSAL PROBLEM*

By Almon L. Fales

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The plating waste disposal problem reported here is one that concerns an industry engaged in the production of metal parts for aircraft engines.

Prior to going to the plating departments, the metal parts are treated by degreasers. The process consists of treating the metal with trichlorethylene to remove any grease adhering to the metal; the used solvent containing the grease is distilled, the trichlorethylene being returned to the process and the still bottoms burned in the boiler furnaces at the power house. The only waste discharged from this process is the cooling water, which is practically clean and involves no disposal problem.

Readings of the meters on the water supply to the plating rooms indicate that the quantity of water used here may amount to as much as 600,000 g.p.d. There was not a wide variation in the hourly rate.

Sources of Wastes

The wastes derive from the following kinds of plating: cadmium, chromium, copper, indium, lead, nickel, silver, tin, "Dulite" for forming an oxidized coating on aluminum, and "Parkerlubrite" for forming a phosphate coating. The plating takes place in standing baths, after which the metals are washed with relatively large quantities of clean water by means of continuous rinses. In addition to plating, there are various stripping operations which are the reverse of plating.

Present Method of Disposal

The wastes from the plating department at the time of dropping (emptying) standing baths are intended to be pumped to sanitary sewers connecting with the municipal sewer system, the sewage of which is to be treated by sedimentation with sludge digestion, elutriation and mechanical dewatering. The wastes at other times are discharged into a storm drain emptying into a small brook which is polluted to such an extent that the state authority has ordered abatement of the pollution.

There is a large river a little over one-half mile distant from the plant, which might be utilized for disposal of wastes or effluents.

Standing Baths

There are over fifty standing baths in the plating department that are dropped (discharged) after periods varying from one week or less to one year or longer. They are generally kept up to strength by fortifying until they must be renewed. The volumes of solutions in the standing baths vary from a few gallons in crocks to as much as 3000 gal. in tanks. With some exceptions, the time of dropping standing baths is under the control of the laboratory.

Information was furnished in regard to the composition of the solution in each bath and the number of times each bath was dropped during a period of four months. During this period nearly all the standing baths were dropped at least once and some were dropped several times. The indium bath is never dropped, and the subsequent standing rinse is not discharged

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until the laboratory has had opportunity to recover the indium in it. In the case of cadmium plating the solution is filtered but not dropped. In the cases of silver and copper plating, carbonates are generally removed once or twice before dropping the baths.

The principal contaminants in the standing baths dropped are acids or alkalies and toxic substances including cyanides, chromates, fluorides, copper and lead. Cyanides computed as sodium cyanide in one day may amount to 118 lb. from the cyanide baths, 16 lb. from the copper strike and 70 lb. from the silver strike, a total of 204 lb. The quantity of lead salts discharged in one day may amount to 112 lb. computed as lead, from the dropping of a single lead-plating bath. The major source of chromates is the dropping of chromic acid baths used in copper stripping. There are two tanks, both of which may be dropped in one day, carrying a total of 400 lb. of chromic acid.

These standing baths, although small in volume, are so strong that they are unsuitable for discharge into the sanitary sewers for inclusion with the municipal sewage to be treated, even after neutralizing excessive acidity or alkalinity. They must be treated, either alone or with some other wastes, before discharge into the brook or river.

Rinse Waters

With the exception of the rinses after tin immersion, which was not in use at the time of this investigation, the flow of each running rinse after the bath was estimated by taking the time to fill a bucket of known volume. Samples of each rinse water were collected at 15-min. intervals to form a 7-hour composite sample. These composite samples of the individual rinse waters were examined to determine the pH, alkalinity or acidity, and the amounts of copper, lead, chromium, cyanide or fluoride, according to the nature of the rinse water under examination.

Most of these rinse waters were found to be weak, but some contained considerable amounts of acid or alkali, copper, hexavalent chromium, cyanide, lead, or fluoride. The differences were not sufficient to warrant consideration of segregation of different rinse waters for separate treatment or disposal. When mixed together, these rinse waters, if unaffected by the dropping of baths, would naturally contain smaller concentrations of constituents than those in some of the individual rinse waters. If the standing baths discharged should be treated separately from the rinse waters, the indications are that the latter would be suitable to discharge to the river, although it would be desirable to make provision for chlorination of these rinse waters to oxidize the cyanides if they should become objectionable in amount.

Combined Plating Wastes

Representative samples of the combined wastes from the plating department were obtained from each of the three shifts on January 14, 1947. These samples had a very slight or slight yellow color, a very slight turbidity, and a slight to distinct amount of suspended matter. The results of analyses of the composite samples are given in Table I.

The results show considerable differences in the composite samples for the three shifts, but it was reported that they were not much affected by the dropping of standing baths except for one lead-plating bath. The plating room wastes are naturally much stronger in different constituents at the times of dropping the standing baths.

The indications are that the plating department wastes, even after neutralizing the excessive acidity or alkalinity, including the standing baths dropped,

TABLE I.—Results of Analyses of Composite Samples of Plating Room Wastes for Each of Three Shifts, January 14, 1947

(Results in parts per million except as otherwise indicated)

Item	First Shift	Second Shift	Third Shift
Color, Platinum Standard	10	28	25
Residue on Evaporation:			
Total solids	518	348	146
Loss on ignition	290	147	71
Fixed residue	228	201	75
Suspended Solids:			
Total	10.5	50.0	19.5
Loss on ignition	2.0	10.0	6.0
Fixed residue	8.5	40.0	13.5
Settleable Solids (% by vol.)	0.25	0.40	0.10
pH	3.06	6.25	3.03
Alkalinity, $CaCO_3$	—	56.5	—
Acidity, $CaCO_3$ equivalent	232	—	233
Copper	0.5	1.0	0.2
Lead	140.0	2.0	21.0
Fluorides	71.7	0.6	9.3
Cyanides	4.0	1.9	7.2
Chromium:			
Total	1.8	1.7	None
Hexavalent	0.4	0.7	None
Trivalent	1.4	1.0	None

would be unsuitable to discharge into the sanitary sewers for inclusion with the municipal sewage to be treated, and would be objectionable to discharge either into the brook or river without prior treatment.

Chemical treatment tests on the composite sample for the first shift showed that the addition of a ferrous sulfate solution in the proportion of 0.044 lb. of copperas per thousand gallons of the wastes left no hexavalent chormium and only a trace of ferrous iron. The pH was reduced to 2.80 and the supernatant water was very turbid and had a slight yellow color. When milk of lime was added in the proportion of 0.125 lb. of hydrated lime per thousand gallons, there was excellent floc formation, and after settling one hour the supernatant was clear and contained only a trace of heavy metals.

Very little sludge was formed by the ferrous sulfate treatment. The subsequent treatment with milk of lime produced 0.92 per cent by volume of sludge having a water content of 96.6 per cent and a total solids content of 3.4 per cent. This sludge contained relatively little organic matter, as shown by the fact that the loss on ignition of the total solids was only 11.9 per cent.

Alternate Methods of Treatment and/or Disposal

Two general methods of treatment and/or disposal of the wastes from the plating department have been considered:

1. Storage of the combined wastes at times when standing baths are dropped, and uniform discharge of the stored wastes into the rinse waters during at least one shift; chemical treatment of the combined wastes throughout the 24 hours, with discharge of the effluent into the brook and dewatering of the sludge for disposal in a solid form.

2. Collection of the standing baths when ready to be dropped by means of tank trucks equipped for pumping out the bath tanks, and transporting to treatment tanks for chemical treatment to remove objectionable constituents, with discharge of the effluent to the brook or to the rinse waters, and discharge of the rinse waters to the river with no treatment except provision for chlorination to oxidize cyanides if they should be present in an objectionable amount.

The indications are that the latter method of disposal would be the least expensive.

Chemical treatment of the combined wastes from the plating department would involve reduction of the hexavalent chromium with ferrous sulfate or sulfur dioxide, using sufficient milk of lime to maintain a pH above 5.0 to prevent the liberation of hydrocyanic acid gas, and chemical precipitation

with sufficient milk of lime to remove the heavy metals, with dewatering of the sludge produced, and chlorination of the effluent to oxidize any remaining cyanides.

The standing bath solutions will require similar treatment, but the treatment will be varied somewhat according to the kind of standing baths being treated. Sulfur dioxide will be used for reduction of hexavalent chromium, which will permit the recovery of chromium later if found expedient to do so.

POLLUTION PROBLEM RECOGNIZED 50 YEARS AGO

Steps designed to abate pollution of the Nation's water resources began only 50 years ago when it was realized that impure drinking water was causing typhoid, dysentery, and other diseases. In 1900 the death rate from typhoid fever was 35.8 per 100,000, and there were only 60 municipal sewage treatment plants in the entire United States.

Before the pollution became excessive, the stream or lake had purified itself through the ability of large bodies of water to absorb foreign matter. But as time went on and increasing quantities of sewage and industrial wastes were dumped into it, the stream or lake could no longer "swallow" the large additions of waste. The need of treatment of the sewage and waste before its channelling into the water became imperative. By 1935 there were approximately 3,700 municipal treatment plants, serving about 41 per cent of the United States population. From 1933 through 1938 Federal aid was given States for pollution abatement as part of a Federal works program. In this 6-year period, the National Resources Committee reported, more progress was made in abatement of municipal wastes than during the entire 25 years preceding, chiefly as a result of Federal financial stimulation.

Modern sewage treatment was inaugurated by Massachusetts in 1886 when the State legislature placed the inland waters of the Commonwealth under the jurisdiction of the board of health and provided funds for the Lawrence Experiment Station. At this station engineers, chemists, and biologists were given the opportunity to work together on the problem of municipal waste. Many specific treatment methods and equipment designs were pioneered at Lawrence.

In 1913 a water and sanitation investigations station was established by the U. S. Public Health Service in Cincinnati. Although originally concerned only with the investigation of the Ohio River pollution, the station is now active in basic and applied research and the training of personnel. Important contributions to the knowledge of water purification, sewage, and industrial waste treatment have been made by researchers at the station. Through the provisions of the Water Pollution Control Act which became law in the summer of 1948, the Cincinnati station was authorized an appropriation of $800,000 a year for the five fiscal years beginning with July 1, 1948, for expansion of technical and research facilities and the training of pollution control personnel. The Act is the first federal legislation aimed at reducing the pollution of our water resources. The Act is expected to be instrumental in launching a systematic program of pollution control and abatement with the cooperation of State and interstate agencies.—*United States Public Health Association.*

INDUSTRIAL WASTE POLLUTION ABATEMENT PROGRAM FOR BUFFALO, N. Y.*

By George E. Symons,† George F. Fynn, and Howard Brown

Consultant, Chief Chemist, and Research Chemist, Respectively, Buffalo (N. Y.) Sewer Authority

The Buffalo River at Buffalo, N. Y. is a dredged basin of some 165,000,000 cu. ft. extending a distance of nearly 6 miles from Buffalo Harbor to the confluence of the Buffalo and Cazenovia Creeks. Through this basin flows the drainage from 436 square miles. During winter months and following storm precipitation the flow is relatively large and has on one occasion been estimated at 27,000 c.f.s. During the months of May to October each year, however, the average flow of water through this basin is less than 100 c.f.s., and during the summer months the flow has been less than 20 c.f.s. for several weeks at a time, especially when the precipitation has been below normal.

In the past, this basin has received large quantities of domestic sewage and industrial wastes; it still receives large amounts of industrial wastes. Under conditions of low flow it becomes grossly polluted and is a vast septic tank in which nuisance conditions are created. Under the influence of a sudden storm on the watershed the basin may suddenly spew its septic contents into the Niagara River, killing fish and adversely affecting existing water supplies in the river below Buffalo. There are recorded instances of these effects in the past, and a continued septic condition in the basin is a potential threat that such adverse effects might again occur under certain conditions of flow.

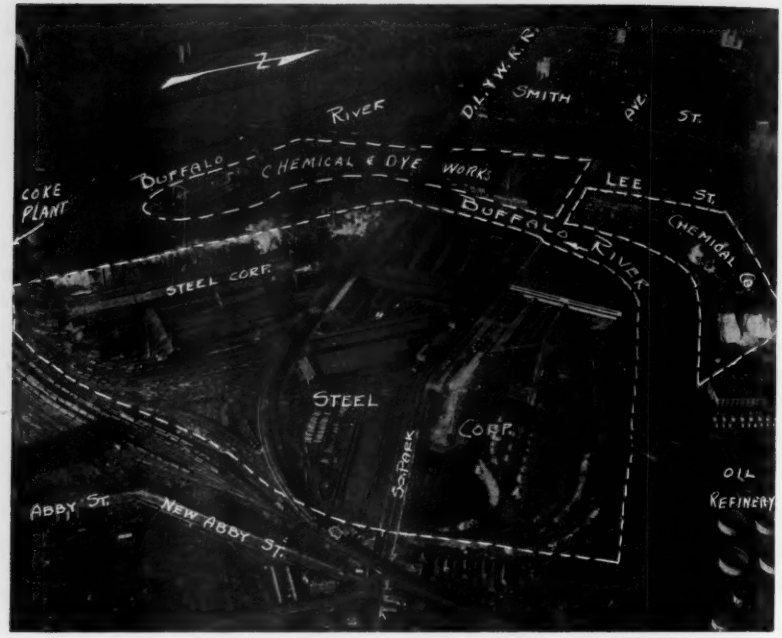
With the creation of the Buffalo Sewer Authority in 1935 the way was paved for the adoption of a program of pollution abatement of the waters in and about Buffalo. This program unfortunately was interrupted with the advent of World War II. Although sanitary wastes were largely removed from the Buffalo River before the war, industrial wastes have continued to be discharged. In spite of efforts on the part of industry to reduce the waste load, the increase in industrial production in the past several years has caused an increase in industrial waste load.

Realizing that the polluted condition of the Buffalo River was becoming worse and that to offset the potential threat of this condition the program of pollution abatement needed to be reinstated, Mr. Henry W. Keitzel, then Chairman of the Buffalo Sewer Authority, brought together representatives of the New York State departments of health and conservation, the industries located on the Buffalo River, and the Buffalo Sewer Authority. From these various conferences in April and May, 1946 there was developed a program of cooperative study to ascertain the pollution load on the Buffalo River at that time and the condition of that stream as a result of this pollution load.

This report is a summary of the results of these investigations, together with certain proposals as to steps to be taken to abate the nuisance condition in the Buffalo River and to minimize, if not eliminate, the potential pollution threat to existing water supplies in the Niagara River.

Presented at Twentieth Annual Meeting, New York State Sewage Works Association, New York City, January 23, 1948.

† Also Associate Editor, *Water and Sewage Works*, New York, N. Y.



Air view of industrial section on Buffalo River.

Results of Early Studies

The original studies of the pollution of the Buffalo River began in 1936 as a part of the investigations of Greeley and Hansen, Engineers for the Buffalo Sewer Authority, in connection with the design and construction of intercepting sewers and a sewage treatment plant for the city of Buffalo.

At that time analyses were made of the wastes from the major industries having waste outlets into the Buffalo River. Stream pollution surveys of the river itself were conducted at regular intervals for the next 5 years. The results of these early studies for the 45-month period ending in December, 1939 were published in THIS JOURNAL in May, 1940. The studies were discontinued in early 1942. The data of 1940–42 are included in this paper.

The results of the 1936–39 studies may be reviewed briefly as follows:

1. Prior to July 1, 1938, on which date sewage treatment was inaugurated in Buffalo, the Buffalo River received daily a pollution load equivalent to the wastes from 244,000 persons.

2. After July, 1938 the domestic sewage from 82,000 persons was no longer discharged to the Buffalo River, but instead was discharged to the city interceptors for treatment in the sewage works.

3. After July, 1938 the industrial waste load on the river was reduced by an amount equivalent to the waste of 63,000 persons. This reduction was accomplished by remedial efforts on the part of the several industries.

4. After July, 1938 studies of the Buffalo River indicated that the B.O.D. of the river had been reduced by 57 per cent and the coliform bacteria content of the river had been reduced by 75 per cent, as a result of the remedial

measures adopted by the Sewer Authority and the industries.

Program of 1946 Studies

For the 1946 investigation, sampling stations on the Buffalo River were the same as those used in previous studies (Figure 1) except that no samples were collected from the mouth of the river and only one sample was collected from each of the tributary streams above the point of confluence.

Between May 2 and Oct. 9, 1946, inclusive, eleven sampling surveys were made. The flow in the river at the time of sampling was determined from data taken from recording gaging stations and supplied by the U. S. Geological Survey. All surveys were made at times when the flow was unaffected by storm precipitation. Analyses were made in the laboratory of the Sewer Authority, and standard analytical procedures were used.

In addition to these biochemical surveys of the river, special studies were also made of the wastes from the five major industries located on the Buffalo River. At these industrial plants arrangements were made with the company representatives to sample the discharges from the individual outlets as well as the raw river water where pumped for plant use.

Samples of industrial wastes were collected at hourly intervals and composited at the end of the day in accordance with the flow each represented. The composite samples were analyzed in accordance with standard procedures, or in special cases in accordance with technics agreed upon before the studies were undertaken.

Sampling periods ran for 14 days at three plants, for 10 days at one plant, and for 7 days at another plant. The difference in length of study was dictated in part by the complexity of the problem and in part by availability of sampling personnel.

After the completion of each industrial waste study the data were tabu-

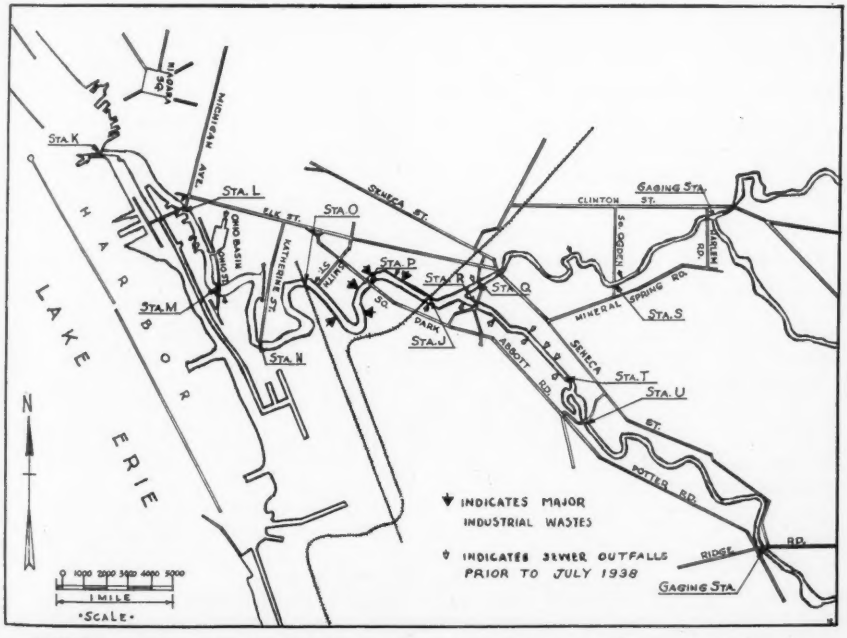


FIGURE 1.—Map showing locations of sampling stations and five major industries.

lated and a report prepared on the pollution load from that particular plant. Copies of these individual reports were distributed to the industry concerned, as well as to the New York State departments of health and of conservation.

In addition to the sampling done by the Sewer Authority, the mobile laboratory of the New York State Department of Conservation collected special samples from three of the industries. These samples were subjected to bioassay and the results were reported to the Department of Conservation and the Sewer Authority, and were made available to the industries concerned.

An investigation was also made of all of the other industries discharging wastes to the river, either directly or through septic tanks. In one particular area, generally known as the Ganson-Ohio-Childs Sts. area, where 32 industries are located, samples were collected and analyzed from five plants having wastes other than sanitary sewage. This area is not now served by an interceptor. As a result of this study preliminary plans and estimates have been made for a sewer system to serve the area. Information on the pollution load from these various miscellaneous industries was included in the summary.

Pollution Load in 1946

The data from the individual reports are summarized in Table I, which shows the flow and the various polluting constituents of the wastes entering the river in 1946. The data in this table, when totaled, give a measure of the total pollution load then being imposed. There has been some improvement since 1946, but for all practical purposes, abatement has only begun.

An inspection of Table I reveals a number of facts about the pollution load on the Buffalo River. The total flow of wastes is more than twice the average of the observed river flow for the summer period of 1946, and is more than six times as much as the minimum flow of 20.8 m.g.d. More than 90 per cent of this waste flow is water pumped from the river for cooling purposes. This cooling water, itself, introduces no waste load. Into the cooling water discharge is dumped, however, all of the industrial wastes, and it is the strength of these industrial wastes that is indicated by the data in Table I.

Biochemical oxygen demand data indicate that the present load is equivalent to the domestic waste from 221,000 persons. This is approximately 91 per cent of the load existing in 1936 be-

TABLE I.—Wastes Entering Buffalo River in 1946

(Results in Thousand Pounds Per Day)

Type of Waste	Flow (m.g.d.)	Susp. Solids	Acidity	Chlor. Dem.	SO_4	Iron	Phenol	SCN & CN	B.O.D.	Thous. P.E.
Oil refinery[1]	20.5	−11.4	+0.39	0.41	2.51	−1.35	0.013	Tr.	5.58	32.9
Heavy acids	5.75	−0.06	2.53	−0.06	5.52	−0.08	—	—	−0.46	−2.6
Org. chem. and dyes	21.1	33.0[2]	32.6	22.1	105.0	7.59	0.671	0.285	27.7	163
Steel	61.6	22.6	−5.63	−1.23	9.7	5.22	0.440	0.200	−3.55	−21.0
Coke	11.5	5.37	−3.81	6.71	13.3	0.23	1.078	0.593	6.18	36.2
Miscellaneous[3]	6.51	—	—	—	—	—	—	—	1.48	8.7
Sanitary sewage[4]	0.21	—	—	—	—	—	—	—	0.56	3.3
Total	127.2	49.5	26.08	27.9	136	11.4	2.20	1.08	37.5	221.0

[1] This plant also discharges 690 lb. of oil per day.
[2] Apparently largely due to neutralization of acid wastes.
[3] 44 miscellaneous industries.
[4] Sanitary wastes from miscellaneous industries.

fore the sewage discharges were removed from the river and before the industries instituted measures for the reduction of waste loads. It is interesting to note that the operations of the steel furnaces and the inorganic acids production actually destroy B.O.D. equivalent to 23,600 persons. These observations show definitely that remedial measures taken by the various industries as a whole have not kept pace with production, over the past 8 years.

Chlorine demand is also shown as a measure of waste concentration, but there is no thought that these wastes might be subjected to chlorination.

Suspended solids data, another criterion of waste load, likewise indicate a heavy load on the stream. In this connection it is well to note that were it not for sedimentation taking place in the oil trap of the oil refinery, the suspended solids load on the river would he higher by some 11,000 lb. per day. On the other hand, it should also be noted that the high suspended solids discharge in the organic chemical and dye wastes is believed to be caused by precipitation of inorganic salts when those wastes are limed to reduce the acidity. It is believed that most of these inorganic salts may become soluble under the influence of dilution in the stream. The total actual suspended solids load from this particular plant may therefore be less than 10,000 lb. per day, in which case the true suspended solids load discharged into the river would be approximately 26,000 lb. per day.

Acid discharged to the river in 1936 was equivalent to 97,000 lb. of calcium carbonate per day, and in 1940 was approximately 40,000 lb. per day, but the present equivalent acid load has been reduced to 26,000 lb. per day in spite of increased production. This change is largely due to the practice of liming the wastes in the organic chemical and dye plants. Some beneficial alkalizing effects are also obtained as a result of alkalinity obtained from the processes of steel and coke manufacture.

Iron, which is a source of color and turbidity in the river in the presence of sulfides, comes mainly from two plants.

Sulfates amounting to 136,000 lb. per day serve as an ample source of material for the production of sulfides under the septic conditions prevailing.

Oil losses to the river amounting to approximately 700 lb. per day come from the oil refining operations. In addition there is oil waste discharged to the river from the bilges of vessels plying the stream, but the amount of this oil cannot be estimated.

Phenols, cyanides, and thiocyanates are discharged from four plants, with the greatest amount coming from the coking plant, although the chemical and dye wastes also contain these substances.

It is these wastes, among others, which may be classed as toxic to fish life. Tests made by the mobile laboratory of the Department of Conservation indicated that high temperature, low pH and oxygen depletion, all of which exist in the stream by virtue of its use by these industries, are in themselves inimical to fish life.

In addition, the bio-assay tests indicated that (1) the wastes from the oil refining plant contain substances capable of producing rapid mortality of fish life when discharged into the stream at periods of low flow; (2) even after pH adjustment and aeration the wastes from all but one of the outlets of the chemical and dye works contained substances toxic to fish life, unless diluted more than five times, and at least one individual waste was toxic in dilutions greater than 5000 times; (3) at least three individual process wastes from the coking plant are extremely toxic even in dilutions of 50 to 100 times, and the final effluent from the plant itself is highly toxic in dilutions up to 50 times.

The mobile laboratory staff points out that in addition to phenols and cyanides, other toxic wastes may be present as follows: from the oil refinery—sulfur compounds, phenolic compounds, phenylates, naphthenic acids and derivatives, quinoline, pyridine, thiophenes, ammonium compounds, and salts of heavy metals; from the chemical and dye works—benzol, nitrobenzene, zylol, and zylene derivatives; and from the coking plant—organic compounds of undetermined nature.

Condition of the Buffalo River in 1946

The condition of the Buffalo River as determined from the eleven surveys in 1946 is presented in two graphs and a table, with all data being calculated on a quantitative basis.

Figure 2 shows the average 5-day B.O.D. and the coliform bacteria content at each of the several stations for the four periods (prior to July, 1938; July, 1938, to Dec., 1939, incl.; Jan., 1940, to Feb., 1942; and May to Oct., incl., 1946). In interpreting these data it should be borne in mind that the average flow was 217 c.f.s. in the first period, 129 c.f.s. in the second, 203 c.f.s. in the third and 70.6 c.f.s. in 1946. Thus, more diluting water was available in the earlier periods than in 1946. It should be noted also that the 1946 period is for the months of worst conditions, whereas the previous data include other months of the year. In short, the 1946 period of worst conditions is compared to the average year-round conditions of previous years.

Although the 1946 data represent the worst conditions of the year, it still is apparent that the river generally is not as bad as the average condition of the same stream in 1936–38,

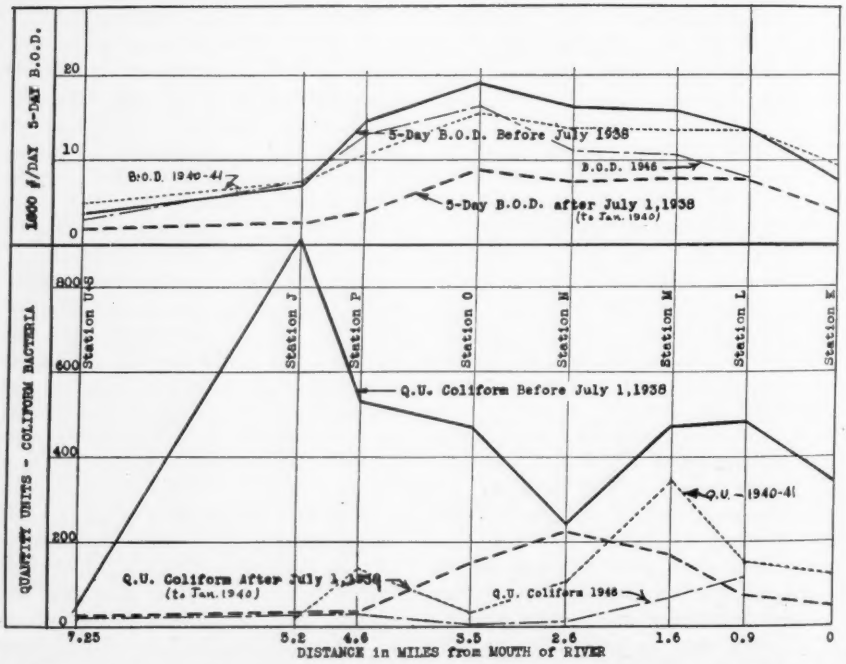


FIGURE 2.—Curves showing 5-day B.O.D. and coliform quantity units at various sampling stations for four different periods.

TABLE II.—Average Condition of Buffalo River at Stations P, O, N, M, Months of May to October

(Results in Thousand Pounds Per Day)

Item	May, 1936 to June, 1938, incl.	July, 1938 to Oct., 1939, incl.	May, 1940 to Oct., 1941, incl.	May, 1946 to Oct., 1946, incl.
Flow-c.f.s.	118	59	77.5	70.6
Dis. Oxygen	0.13	0.06	0.17	0.27
B.O.D.	11.3	4.65	8.7	9.64
Susp. Solids	42.8	21.0	27.9	25.3
Coliform Q.U.	329	162	153.7	13.9

although it is considerably worse than the average condition in 1938–39, and about as bad as in 1940–41.

The coliform bacteria content is greatly improved over previous conditions, although in 1946 there appears to be a tendency toward an increased growth of bacteria as the river nears the harbor and becomes diluted with lake water.

The data in Figure 2 are presented on a quantitative basis, but it may be stated that in 1946 the highest *average* concentrations represented were 25 p.p.m. of B.O.D. at Sta. O and 1150 coliform bacteria per ml. at Sta. L. The maximum B.O.D. observed in 1946 was 69 p.p.m. at Sta. P on Sept. 25.

It has been observed from previous studies that as the river nears its mouth at the harbor there is a diluting effect of the lake water on the river. This effect is apparently caused by a combination of interchange of water of different density and by natural mixing brought about by ebb and flow caused by changes in lake level.

Because of these diluting effects of Lake Erie tidal movements in the lower end of the basin, it has been the practice to determine the average condition of the worst section of the basin (i.e., Stations P, O, N, M) as a better measure of the true effects of industrial wastes being discharged into the basin. Table II shows these average data for the periods of low flow only (i.e., May to Oct., incl.).

As a corollary to Table II data on the average quantities of waste load at Stations P, O, N, M have been plotted for the months of May to Oct. for each of the years 1936–1941, and for 1946. This graph (Figure 3) shows that the B.O.D. load decreased markedly after July 1938, but in 1946 it was almost as high as it was in 1936; it was twice as high in 1946 as it was in 1938–39. (These 1946 data are for ten surveys. If an eleventh survey, when the flow was 337 c.f.s. is included, then the average flow becomes 96.7 c.f.s. and the average B.O.D., 12,900 lb. per day; i.e., higher than in 1936–37.)

The improvement in the bacterial content of the basin is evident from the graph. The dissolved oxygen content, which appears as a few hundred pounds per day, is actually absent most of the time in all summer months. A few surveys, when there is an appreciable flow (but no storms) present through the basin, may show enough dissolved oxygen to produce a small average quantity of D.O. for the entire season.

It becomes obvious from Table II and Figure 3 that the nuisance condition of the Buffalo River in the summer months is almost as bad (if not worse) than it was before any remedial efforts were made to improve it.

It is of interest to note that a study of the data on iron content of the river itself indicates that the apparent iron input by the industries is carried in solution or in colloidal suspension throughout the length of the river.

The data also indicate the disappearance of a substantial portion of the

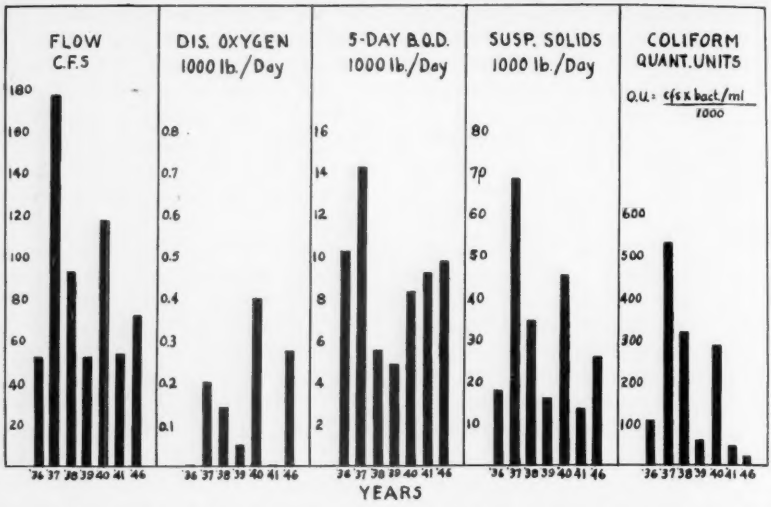


FIGURE 3.—Condition of Buffalo River at Stations P, O, N, M during months of May to October, inclusive, for the seven years of 1936–41, inclusive, and 1946.

sulfate discharged into the river, probably by reduction to sulfides under the influence of septic conditions and the absence of oxygen. If sulfide is produced, as seems likely, then the iron probably is converted to colloidal iron sulfide and remains in the water, producing much of the color in the stream in its lower reaches. In previous studies this compound has been found to be a source of color and turbidity. Color in the upper portion of the basin is largely a matter of the color of the waste being discharged from the chemical and dye works at the time of observation.

Industrial Cooperation

No report on the condition of the Buffalo River would be complete without mention of the accomplishments that have been made by industry in an effort to reduce the load on the river. While it may be said that the stream is almost as bad now as it ever has been, it almost staggers the imagination to think what the condition of this stream might have been had no remedial measures been practiced since 1938 by the several industries. It is estimated that on a B.O.D. basis the load would have been equivalent to more than 600,000 persons, or nearly three times the present load.

In addition, phenols, pickling liquors, acids, and iron discharges have been reduced, and in one instance, a highly toxic waste was disposed of at sea instead of being dumped into the Buffalo River.

All of these improvements and efforts have been accomplished in spite of greatly increased production in all plants, and it is estimated that the accomplishment of these reductions has cost the industries, as a whole, more than a million dollars. In some instances remedial measures have been economically successful in recovery of by-products, but this is not true in all cases.

All five of the industries cooperated in carrying out the studies during 1946 and have actively been considering ways and means of experimenting on methods for further reduction of industrial wastes.

One may well commend the indus-

tries for their efforts both past and present, but one cannot deny the fact that as long as the load on the river is being increased in spite of remedial measures, the problem of pollution is not being solved. Ways and means must be found for actually reducing some of the present load on the stream, and for preventing any increase in that load after reduction, regardless of increasing production.

Program for Abating the Nuisance

From consideration of the data obtained in these studies, from review of previous work, from observation of the river, and from conferences with representatives of the industries and the state departments of health and conservation, the senior author formulated a program for abatement of the nuisance now existing in the Buffalo River as a result of industrial wastes being discharged thereinto.

This program as set forth in the senior author's final report as consultant, has seven basic parts which may be outlined as follows:

"1. Adoption of a project to obtain water direct from Lake Erie for use as cooling water by the five major Buffalo River industries.

"2. Participation of the five major industries in that project as consumers, if not as mutual suppliers.

"3. Acceptance of the principle that the Buffalo River will never again be a trout stream, *but* adoption by voluntary and mutual action of all interested parties of a standard of pollution for the Buffalo River; this standard to have as its basis a maximum allowable pollution load of no more B.O.D. than wastes equivalent to a population of 125,000 persons, or that the pollution load shall not deplete the dissolved oxygen content of the river during the summer months below 0.5 p.p.m., or that the B.O.D. of the stream itself shall be no more than 10 to 15 p.p.m., at periods of lowest stream flow, or whichever standard requires the least reduction in present load. (Although these figures were arbitrary, they did serve as a guide to the general standard to be adopted.)

"4. Acceptance by the industries of the basic tenet that the cost of waste treatment is a legitimate part of production costs regardless of the economics involved in any possible by-product recovery.

"5. Adoption by the five major industries of such means as are now available to reduce their present B.O.D. loads by approximately 50 per cent; to eliminate phenols, cyanides, and other toxic substances where possible; and to practically completely eliminate the discharge of iron to the river.

"6. Adherence by industry to the standard set for this stream to the extent that waste from new processes or increased production will not cause the waste load to exceed that permissible under the standard adopted.

"7. Construction by the Sewer Authority of intercepting sewers in the Ganson-Ohio-Child Sts. area and in Erie St. to make possible the removal of industrial and sanitary wastes equivalent to a population of 12,000 persons, and the construction of sewers (or enlargement of existing sewers) where such a program is necessary in order to accept such wastes from these several industries as may be deemed advisable to be taken into the city sewers.

"The casual and uninformed reader may complain that this program costs too much, is impractical, imposes too much burden on industry, or does not return the stream to its native purity. Saner consideration of the factors involved in these points and of the benefits to be derived show that such an opinion is quite wrong. In the following paragraphs the above points are expanded upon.

"Perhaps one of the first considerations on which all parties concerned must agree is that the Buffalo River cannot be expected to become a fish stream again, because in light of present knowledge complete elimination of wastes from the river is impossible unless the industrial plants discontinue operations.

"On the other hand, it seems highly probable that the adoption of the above program will practically, if not entirely, eliminate (1) nuisance conditions, (2) threat to existing water supplies in Niagara River, and (3) threat to fish life in the Niagara River.

"Heart of the above program is the construction of a project to bring cooling

water from Lake Erie to the five major industries on the Buffalo River. With the industries requiring approximately 120 m.g.d. now and a possible 200 m.g.d. in the future, the supplying of this volume of clean, cool, alkaline water containing dissolved oxygen would have many benefits. These benefits may be briefly summarized as follows:

"1. Creation of sufficient flow in the Buffalo River during periods of dry weather flow to prevent concentration of waste in the basin and the threat that 'slugs' of this concentrated waste will reach the Niagara River.

"2. Improvement of cooling processes in industry and reduction of maintenance in the plants by virtue of the cleaner and cooler properties of the lake water.

"3. Elimination of corrosion of cooling equipment and elimination of the need for liming to neutralize acid wastes. (The alkalinity of the cooling water will more than neutralize the acid discharged from the industries.)

"4. Elimination of sedimentation of suspended matter in cooling and in treatment equipment, thereby reducing both maintenance costs and improving the operation of treatment facilities.

"5. Provision of some 7000 to 10,000 pounds of dissolved oxygen to the river each day. This amount would supply approximately one-third the oxygen demand of the industrial wastes if these wastes are reduced to approximately 50 per cent of the present load.

"6. Provision of dilution as well as dissolved oxygen, which together would reduce concentration of the wastes and reduce the B.O.D. to a concentration no higher than 10 to 15 p.p.m.; the dissolved oxygen under these conditions may not be completely depleted, except at times of extremely low flow."

Progress in 1947

The senior author's report as consultant was released on Dec. 11, 1946. In the thirteen months which followed considerable progress was made toward implementing the recommended program. Many conferences were held individually and jointly with the industries and the New York State departments of health and conservation. From the conferences came the following results.

1. Agreement of the state departments and the Sewer Authority that the "desirable condition" of the Buffalo River is a B.O.D. of no more than 15 p.p.m. at mean dry weather flow.

2. The industries agreed to attempt to reduce their respective pollution loads to 50 per cent of the 1946 load, and to maintain future loads at or below that level.

3. The industries estimated that their needs for cooling water in the future would total 175 m.g.d.

4. On the basis of this estimate, the Sewer Authority made a preliminary estimate of design and cost of a water supply to furnish that volume of water. It was estimated that the cost would be $5,000,000 and that the cost of this water supply to the industries would be 9.55 cents per 1000 cu. ft. at present consumption and less at future expected consumption.

5. The local management and technical staffs of all five of the industries had agreed that the cooling water project was feasible. Top management of the industries has stated their desire to have the Sewer Authority develop a contractual agreement for consideration by the industries. Work on that agreement has begun.

6. Work by the several industries toward reducing their wastes was inaugurated. This progress has included the following:

(a) Preparation to install recording-alarm pH meters to check acid losses in the heavy chemicals plant.

(b) Removal of toxic wastes, and improvement of present treatment facilities in the oil refinery.

(c) Continuing study of waste treatment in the organic chemical and dye industry and the adoption of such treatment methods as are feasible. These may include lagooning, chemical

treatment, discharge to city sewers, relocation of sewer outlets, by-product recovery, and bottling up.

(d) Design of a pilot plant to study the treatment by trickling filter of the coke plant wastes.

Summary and Acknowledgment

Following studies of the stream pollution of the Buffalo River at Buffalo, N. Y., certain recommendations were made for abating the pollution of that stream. Definite progress has been made and indications are that the implementation of that program may become a fact although there are still obstacles to overcome.

Acknowledgment by the authors is due to the industrial representatives who, by their coöperation, made possible the sampling of wastes from the several plants. The bio-assays made by the pollution unit of the New York State Department of Conservation were performed by G. E. Burdick, Aquatic Biologist, and M. Lipscheutz, Analytical Chemist. The preliminary design and estimates of costs of the cooling water project were made by Eric Riis Carstensen, Hydraulic Engineer, of the Buffalo Sewer Authority.

Acknowledgment is also due to the representatives of the New York State health and conservation departments who, in conference and by advice, aided in the development of this pollution abatement program for the Buffalo River.

ANNOUNCEMENT OF THE FOURTH INDUSTRIAL WASTE CONFERENCE

The Fourth Industrial Waste Conference will be held at Purdue University on September 21, 22, 1948. Papers and discussions will cover the newest developments in waste utilization and disposal practices.

There will be special sessions on food processing, dairy manufacturing, fermentation processing, oil refining, metal plating, paper manufacturing, chemical manufacturing, and several others. Attention will be given to analytical methods for the character and toxic quantities of the waste materials.

The program has been planned to provide over-all coverage of the industrial wastes field in the first day general sessions and specific coverage of several areas of interest in the second day group meetings.

A PILOT PLANT FOR TREATMENT OF PHENOL STILL (COKE) WASTES *

By Newell L. Nussbaumer

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The coke plant in question produces about 4200 tons of coke per day, and uses about 10 to 11 m.g.d. of water, which is discharged into the Buffalo River, a tributary of the Niagara River, at Buffalo, New York. Among other wastes, about 5800 g.p.h. of phenol still wastes (NH_3) are discharged. The phenol concentration has averaged 520 p.p.m. in the still wastes analyzed. The pH has been over 10.

Table I compares analyses of the wastes in the plant outfall sewer with Buffalo River water upstream from the sewer outlet.

Following is an analysis (reported in p.p.m.) of the still wastes when the flow is 5800 gal. per hr., and the temperature is about 98° F.

CaS_2O_3	210
$CaSO_3$	2550
$CaSO_4$	120
$CaCl_2$	3870
$Ca(CN)$	60
$Ca_2Fe(CN)_6$	16
$CaCNS$	310
CaS	160
$CaCO_3$	840
Phenols	600
Alkalinity ($CaCO_3$)	1500

The pollution of the Buffalo River by waste discharges from this plant has been investigated by both local and state bodies of jurisdiction, who have advised that a type of treatment shall be provided to reduce the B.O.D. by 65 per cent and the phenols by 90 per cent.

The company, of course, desires to accomplish this required treatment at minimum cost. That used by the Dow Chemical Company at Midland, Mich., seemed to be applicable to this situation, without the activated sludge plant.

TABLE I.—Plant Waste and River Water Analyses

(*Results in p.p.m.*)

Description	Buffalo River Water	Plant Wastes
Turbidity	34	46
Total solids	1012	1260
Suspended solids	63	107
Chlorine demand	23	89
Alkalinity	36	71
Chlorides	186	281
Phenols	0.5	11.7*
SCN (thiocyanates)	1.4	7.3
Oxygen consumed	46	113
B.O.D.	50	105

* 1075 lb. per day.

It was decided, therefore, to construct a pilot plant with a capacity of about 32 g.p.m. of total flow, which could accept about 3 g.p.m. of still waste including dilution water, which would be about 1/300 of the total amount of still waste produced. The plans have been completed. Due to delays in delivery of certain parts of the equipment required, the plant will not be ready for operation until the fall of 1948.

Pilot Plant Design

The pilot plant is to consist of the following units (Figure 1):

(a) Settling tank; capacity based upon 24-hr. detention for maximum rate of flow.

(b) Storage tank mixer. Acid is added to the waste in this tank; its capacity is equal to the settling tank.

* Presented at Twentieth Annual Meeting, New York State Sewage Works Association, New York City, January 16, 1948.

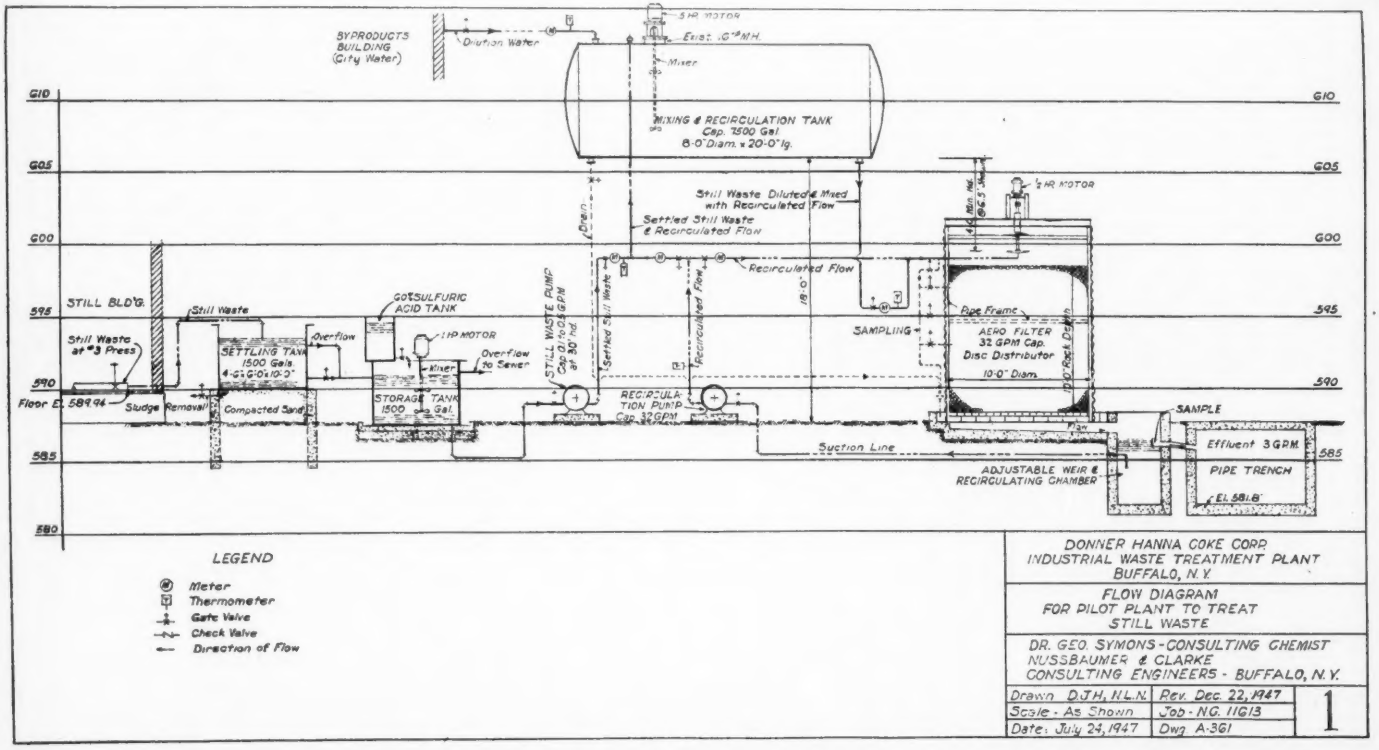

FIGURE 1.—Flow diagram for pilot plant to treat phenol still (coke) wastes.

(c) Still waste pump; capacity 0.1 to 0.5 g.p.m. at 30-ft. head.

(d) Mixing and recirculating tank. Dilution water is added to the waste in this tank, and mixed with recirculated treated effluent. A mixer is provided. The capacity is based upon 1.7 days storage when the rate of flow to the plant sewer is 3.0 g.p.m.

(e) A high-capacity trickling filter with motor-operated disc distributor. The filter is to be 10 ft. in diameter and 10 ft. deep.

(f) Effluent and recirculating chamber.

(g) Recirculating pump; capacity 32 g.p.m. at an approximate head of 35 ft.

(h) Effluent piping to plant drain.

The waste from the ammonia still is discharged from the still through a pipe about 2 ft. above the floor into a funnel connected with the plant drain. The waste is under a pressure of about 3 p.s.i. when discharged. It is planned to withdraw still waste to the pilot plant, after it is in full operation, at the rate of 0.3 to 0.4 g.p.m. As it may not be possible to control flows at such a low rate, it may be necessary to resort to batch mixing in the settling tank for the pilot plant operation. The still waste will be allowed to settle about 24 hours, after which the effluent will flow to the storage tank and sludge will be periodically removed to a dump.

In the storage tank, the settling tank effluent will be mixed with 60 per cent sulfuric acid, the amount depending on the pH, and after a further sedimentation period the mixed liquid will be pumped to the mixing and recirculation tank.

A dilution of the still waste with city water will be made in the ratio of about 1 to 7 minimum to 1 to 14 maximum in the mixing and recirculation tank. After the plant is in full operation, it is expected that the minimum rates can be maintained. It is expected that above 10 cycles of recirculation will be required to produce an effluent that will meet the limits which have been set up for treatment. The effluent weir and recirculating pump, however, are adjustable so that greater or lesser recirculation rates may be used.

The flow from this tank to the trickling filter, when the plant is in full operation, will be at the rate of about 32 g.p.m., including the following elements: still waste—0.4 g.p.m.; city water—2.6 g.p.m.; recirculated flow—29.0 g.p.m. When operating in this manner, there will be a discharge to the sewer of 3.0 g.p.m. The recirculation is accomplished by having the recirculating pump suction connected with the chamber into which the flow from the filter is discharged. The pump operation will be controlled by a float switch.

Unit Loadings

The limiting factors of design are: (1) volume of flow, (2) B.O.D. loading, and (3) phenol loading. The distributor and trickling filter have a capacity of 32 g.p.m., or 46,000 g.p.d. Experience has shown that a loading of 3000 lb. of B.O.D. per day per acre-ft. is considered a maximum, and that a loading of 5 to 9 lb. of phenol per 1000 cu. ft. of filter may be used successfully. To be on the safe side, the 5 lb. rate is used here.

The volume of still waste flow was stated to be 5800 g.p.h., which was rounded to 6000 g.p.h. or 100 g.p.m. The filter can, therefore, treat about 10 per cent of the flow on this basis.

With a filter loading of 3000 lb. of B.O.D. per 24 hours, the pilot plant can handle 540 lb. for 10 ft. of depth, which is about 9 per cent of the total B.O.D. load in the ammonia still waste.

The filter volume is about 785 cu. ft. At 5 lb. of phenol per 1000 cu. ft. the filter can accept about 3.925 lb. per day, which is about 1/300 of the total production.

It is readily seen, therefore, that the

phenol loading is the criterion by which the plant and the filter must be designed.

Study Procedure

During the operation of the pilot plant, it is proposed to observe rates of flow and temperatures of all of the independent elements entering into the combined effluent. In order to test the efficiency of the process under various operating conditions, it is intended to determine the following:

1. *Settled Still Waste*
   a. Alkalinity for acid solution
   b. Phenol and oxygen consumed
   c. Loadings in pounds
   d. B.O.D. and CN
2. *Effluent from Filter*
   a. Phenol and oxygen consumed
   b. Loadings and removals in pounds
   c. B.O.D. and CN
3. *Filter*
   a. Take samples at various depths and test as outlined in (2)

It is proposed to operate this plant for a period of 12 months. If the process is successful in accomplishing the required removal of B.O.D. and phenol, a full scale plant will then be built by the company.

FEDERATION RESEARCH GRANT INCREASED

August 31, 1948, marked the close of the first year of the Federation's research projects on the development of new and improved methods of sewage and industrial waste analysis. Under the coordination of Dr. W. D. Hatfield, chairman of the Federation's Committee on Standard Methods of Sewage and Industrial Wastes Analysis, six research laboratories have been conducting studies which already have produced worth while and tangible results. This work was made possible by a grant of $33,830 by the National Institute of Health.

The Federation's grant has been extended for another year, and has been increased to $48,700. This will insure continuation of the present research projects and will allow the inclusion of an additional laboratory in the program. The new laboratory will be located at Ohio State University where special analyses of wastes from the manufacture of plastics, synthetic rubber, butadiene, synthetic petroleum, penicillium and streptomycin will be studied under the direction of Professor L. Kermit Herndon.

The research work conducted during past years at the Allegheny County Sanitary District Laboratory, under the direction of H. Gladys Swope, was concluded August 31, 1948, and transferred to Purdue University where Professor M. G. Mellon will continue the study of methods for determining copper, chromium, zinc, and other metallic constituents of wastes.

Current research projects of the other cooperating laboratories will be continued during the coming year at the University of Wisconsin (Dr. M. Starr Nichols); Massachusetts Institute of Technology (Dr. Clair N. Sawyer); New York State Health Department Laboratory (Dr. F. W. Gilcreas); Rutgers University (Dr. Willem Rudolfs); and Illinois State Water Survey (Dr. A. M. Buswell).

Stream Pollution

OXYGEN BALANCE STUDIES OF A TYPICAL SWAMP STREAM *

By Stuart C. Crawford

Research Chemist, Camp Manufacturing Co., Inc., Franklin, Va.

This paper represents an endeavor to fill a gap in the technical literature relating to the oxygen balance of streams. Experience has shown over a period of years that if certain dissolved oxygen levels in a stream are not maintained, fish life will be disadvantageously affected. Further, if certain lower dissolved oxygen standards are not met, not only will fish life have difficulty in existing but, in addition, a foul condition of septicity will be encountered.

The minimum dissolved oxygen levels generally accepted are 5.0 p.p.m. for the maintenance of healthy environmental conditions for fish life and 4.0 p.p.m. for the maintenance of other desirable sanitary conditions in the stream. References to substantiate these criteria include the work of Ellis (1), the Ohio River Pollution Survey (2), and Lackey (3).

The author has reason to believe that these standards are of questionable value when applied to swamp streams. They may be applicable in mountain streams of pristine purity and in other streams of low organic content. They are not acceptable, in the author's opinion, where nature has provided sources of high organic loading for streams, and the native aquatic life has become adjusted to the lower dissolved oxygen levels. Further, when additional organic loading is added by man, the rate of assimilation in these swamp streams differs from that of other types of waters.

These opinions have resulted from hundreds of observations on such a swamp stream, the Blackwater River, flowing through southeastern Virginia. A study has been made of the data available since 1938 from a research program conducted by the Camp Manufacturing Company at Franklin, Va., with these objectives:

(1) Determination of the natural dissolved oxygen fluctuations of the stream.

(2) Study of the measurable effects of sulfate pulp and paper mill discharges to the stream.

(3) Selection of methods for reducing these effects to an acceptable level.

The Blackwater River

The Blackwater River rises in Prince George and Surry Counties and flows southeast and south, entering North Carolina as a tributary, together with the Nottoway and Meherrin Rivers, of the Chowan River in North Carolina. Its entire basin lies in the coastal plain of Virginia, comprising 576 sq. mi. drainage area at the nearest upstream gauging station, 3 miles northeast of Burdette, Virginia.

This water is low in mineral content and highly colored from its drainage of the cypress swamps of eastern Virginia. Typical analyses show total solids of 75 to 100 p.p.m., with approximately equal content of fixed and or-

* Presented at First Annual Meeting, Virginia Industrial Wastes and Sewage Works Association, Ocean View, Va., October 16–17, 1947.

ganic solids; chlorides of 3 to 5 p.p.m., and sulfates of 25 to 30 p.p.m. The pH is normally 6.5 to 6.8, and temperature fluctuates from 35° to 85° F.

Figure 1, showing the chemical character of typical Virginia surface waters, has been prepared from published data (4). This indicates the substantially heavier load of organic material in the Blackwater, even when compared with the Nottoway, a sister headwater of the Chowan River.

Figure 2 is derived from survey data based on average figures of upstream conditions collected during the years 1938–1946. Data from this 9-year period have been used in establishing a reference curve of the expected upstream conditions as to oxygen saturation during the various months of the year. Actual minimum conditions which have been encountered for prolonged periods during the years 1945 and 1946 are shown as points in com-

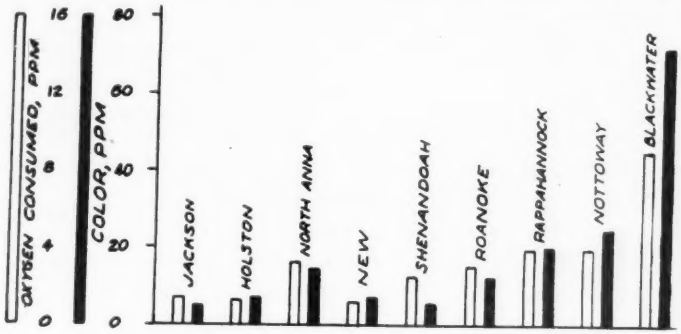

FIGURE 1.—Chemical characteristics of Virginia streams.

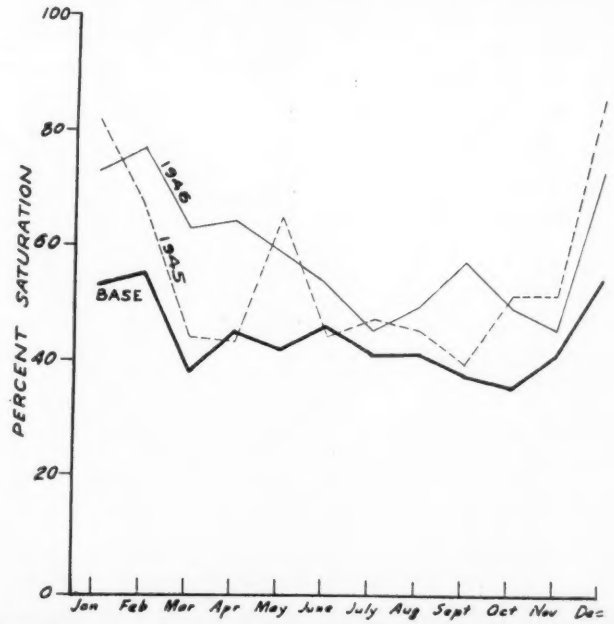

FIGURE 2.—Dissolved oxygen saturation in the Blackwater River.

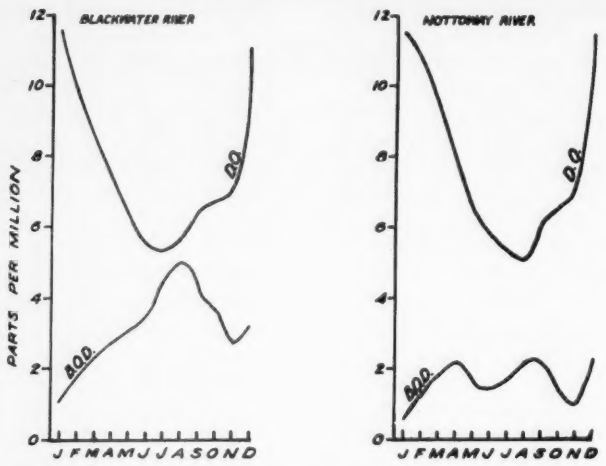

FIGURE 3.—Dissolved oxygen and B.O.D. data for Blackwater and Nottoway Rivers; monthly averages for 1946.

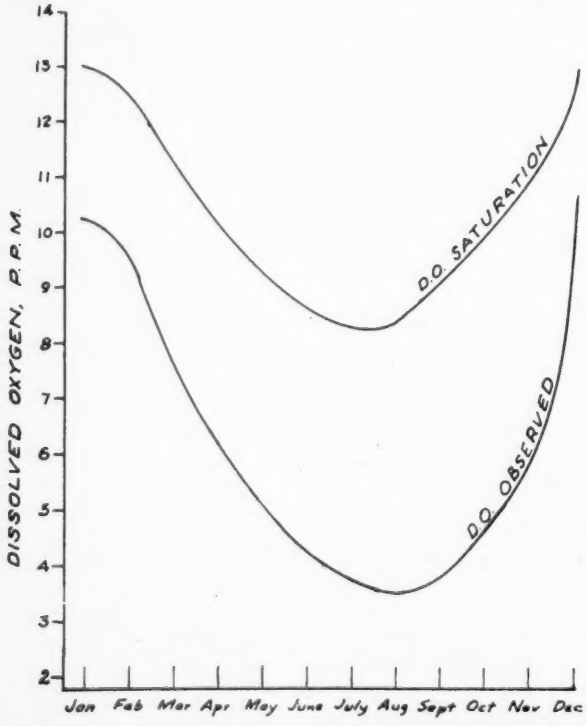

FIGURE 4.—Dissolved oxygen variation from saturation in the Blackwater River.

parison with these base figures. The years selected cover rather typical conditions, and no attempt has been made to present unusual figures.

During 1946 an intensive river survey was conducted, with daily river trips throughout the year. This routine has since been modified to three trips weekly, after evidence was secured that this procedure yielded substantially the same results. Figure 3, based on the 1946 daily survey period, shows the relationship of upstream B.O.D. to dissolved oxygen in the Blackwater, and similar data for the Nottoway. These curves corroborate the other evidence showing the heavy natural pollution loading carried. Figure 4 presents the variation of D.O. from the 100 per cent saturation values as observed in the Blackwater River.

These curves indicate the lack of natural purification capabilities of the Blackwater River. Throughout the survey period it has been normal for the station at Joyner's Bridge, which is 7 to 8 miles downstream from Burdette, to show approximately 0.5 p.p.m. less dissolved oxygen. This figure varies from no effect during the winter months to a lower figure during the high-temperature and low-flow conditions of the summer period. No trend has ever been noticed toward higher results at the downstream station. Indications are that the oxygen input from stream reaeration during the summer is less than the oxygen losses resulting from the natural B.O.D.

No picture of the Blackwater River would be complete without some discussion of its variable flow. While incomplete records are available before 1943, during that year the U.S. G.S. installed a gauging station near Burdette, Va. Since that time a slope-discharge curve has been established and daily records are available. Table I shows the average flow at this point for the years 1943 through 1946.

TABLE I.—C.F.S. Flow in Blackwater River Near Burdette, Va.

(Water Year Ending September 30)

Month	1943	1944	1945	1946
October	466	29	28*	356
November	224	70	50	256
December	465	87	411	958
January	542	762	587	1578
February	1396	1014	1043	1495
March	1000	2452	1006	804
April	897	1213	292	622
May	383	211	445	814
June	377	6*	316	360
July	413	5*	2003	556
August	54	6*	1039	197
September	9	1*	1265	70

* Water diverted to Norfolk, Va. However, such is not abnormal as during August, 1947 flows of under 15 c.f.s. were obtained.

This condition is further accentuated by a tidal effect which extends several miles upstream from Franklin, Va. During periods of flow under 200 c.f.s. the Blackwater River is analagous to a pond with a segment of water moving up and down at the dictates of the tide and of the prevailing wind conditions.

In spite of the comparatively poor natural assets of the Blackwater River, it is regarded as a good fishing stream. It is so considered by the Game and Inland Fisheries Commission of Virginia, and they have stocked it with bass, bream, and perch. Prize fish have been taken from its waters.

Sources of Pollution

There is no significant pollution upstream. The only sources of pollution downstream are located at Franklin, Va.

Untreated sewage from a population of approximately 5000 persons is discharged from the town. Industrial pollution resulting from the operations of a 300-ton per day kraft pulp and paper mill is the initial load from the activities of the Camp Manufacturing Company. Since the building of this mill in 1938, the attempt to abate

stream pollution has been a very important question. Some very real accomplishments have been made by the company in its attack upon this problem. As the development of this work has been previously reported by the author (5) it will not be traced here.

Table II shows the extent of the pollution load imposed by the pulp and paper mill, before treatment was provided and since treatment by selective ponding was initiated.

TABLE II.—B.O.D. of Camp Manufacturing Company Wastes

Treatment	B.O.D. Load to River		Overall Reduction (%)
	Lb. per Day	Pop. Equiv.	
None	25,195	148,200	—
Ponding (1946)	10,078	59,300	60.0
Ponding (1947)*	6,350	37,400	74.9

* July and August data.

It is confidently expected that further refinements to the ponding system will increase the overall reduction substantially.

Summary

In summary, the purpose of this presentation has been to show the natural characteristics of a typical swamp stream, which have complicated studies of the effects of a relatively heavy industrial pollution load, and the accomplishment of a reduction of this load to a point where nuisance conditions may be prevented and acceptable conditions realized.

From this work several conclusions appear pertinent:

(1) Existing concepts of 4.0 to 5.0 p.p.m. of dissolved oxygen for proper support of aquatic life are not applicable to swamp streams where such life has become acclimated to the naturally lowered conditions.

(2) Such standards are contrary to the natural state of these swamp streams and this should be recognized by regulatory authorities.

(3) The same conditions of swampland territory which cause the natural conditions of these streams may provide areas suitable for the acceptable stabilization of wastes.

(4) From the author's observations, the maintenance of 2.5 p.p.m. average dissolved oxygen, with a minimum of 2.0 p.p.m., would provide satisfactory conditions for both the native fish life and the esthetic characteristics of the Blackwater River.

References

1. Ellis, M. M., "Detection and Measurement of Stream Pollution." Bulletin 22, U. S. Bureau of Fisheries (1937).
2. U. S. Public Health Service, "Ohio River Pollution Survey, Volume I" (1942).
3. U. S. Public Health Service, "Special Studies of the James River" (1943).
4. Virginia Department of Conservation and Development, "Chemical Character of Surface Waters of Virginia" (1932).
5. Crawford, S. C., "Ponding of Sulfate Mill Wastes." THIS JOURNAL, **19**, 4, 621 (1947).

DETERMINATION OF THE TIME OF PASSAGE OF POLLUTION IN THE ANDROSCOGGIN RIVER AND POND *

By Walter A. Lawrance

Bates College, Lewiston, Maine

The river odor conditions which exist during the summer in the region of Lewiston and Auburn, Maine, have necessitated a program of research which has for its objective the amelioration and if possible the elimination of the nuisance. One of the major odors is hydrogen sulfide.

The Androscoggin River begins as an outlet to Umbagog Lake, one of a series of connecting bodies of water known as the Rangeley Lakes. These natural lakes, together with artificial storage areas, are the principal sources of water in the upland drainage region. Lake Kennebago at the headwaters has an elevation of 1,774 ft. above sea level. These waters are under strict control, and under normal conditions are allowed to pass into the river only in such volume as will meet the power and industrial needs of the communities located in the valley. The river is not now used as a source of potable water.

The river is highly developed for power purposes; 24 dams have been built from Berlin, N. H. to tide water at Brunswick, Maine, a distance of 135 miles (Figure 1). Gulf Island Dam, just north of Lewiston, is the only one of importance for storage use below Berlin. This dam impounds 2,400 million cubic feet of water in a pool known as the Androscoggin Pond, about 14 miles in length. About 80 per cent of the storage water lies in the southern half of the pond.

Waste sulfite liquor and cellulose fiber from paper mills with some sewage constitute the major pollution load in the river and pond. The liquor and fiber are discharged at widely separated points and at great distances from the area of the odor nuisance. Under the present restricted summer production program, the Berlin, N. H. mills, 112 river miles from Lewiston, may contribute approximately 3,700 tons of liquor per week. The paper mills at Rumford, Maine, 59 miles distant, discharge about 1,600 tons weekly and the production at Chisholm, Maine, 32 miles north of Lewiston, yields about 500 tons of waste sulfite liquor per week. The summer pollution load includes municipal sewage from a population of 38,000 (2), waste liquor equivalent to a population of 1,500,000, and other industrial wastes totaling 150,000 population equivalent.

Summer river flow is principally dependent upon the available storage, and variations are due to the volume of rainfall. During the period of these studies—August and early September, 1945—the flow was fairly constant and averaged 2,100 c.f.s. at the Gulf Island Dam gage.

Under conditions such as exist in the Androscoggin Valley, a knowledge of the times of passage of pollution is important in the interpretation of the analytical data obtained at different locations, and is necessary for calculating the natural self-purification capacities under different pollution loads.

Times of passage are usually determined by volumetric displacement calculations, but in 1945 sufficient data were not available to apply this method to the Androscoggin River system.

* Presented before the Water, Sewage and Sanitation Division, American Chemical Society, Atlantic City, N. J., April 15, 1947.

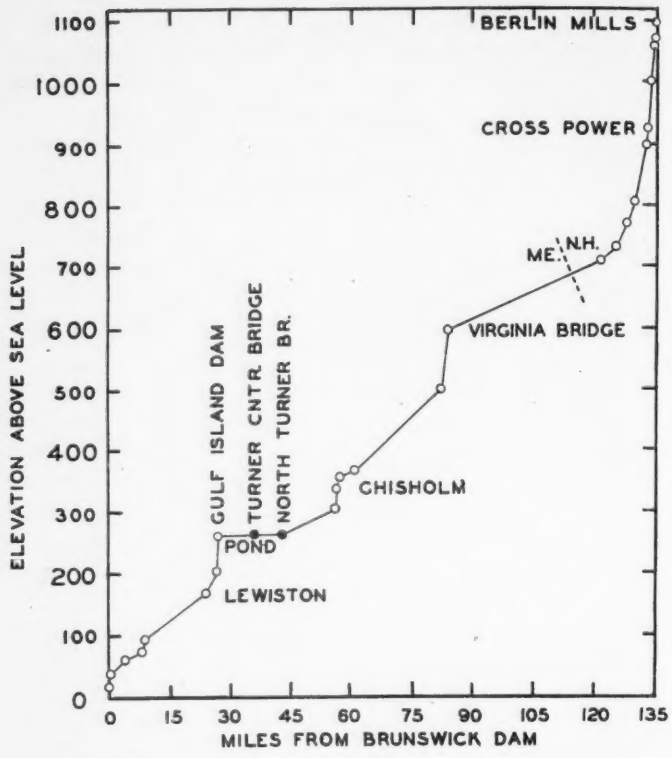

FIGURE 1.—Androscoggin River and Pond, sampling stations.

The presence of islands in the river and pond and of bays in the pond, which are by-passed by the main flow of water, would have made the calculations, with the limited data, very empirical.

In the spring of 1945, The Brown Company of Berlin, N. H., the largest pulp producer using Androscoggin River water, decided to close their mills for a weeks' vacation in August. This shut-down provided an opportunity to study the effects of the diminution and then increase of the pollution load in the river and pond. Fortuitously, the V-J Day celebrations came during the vacation week, and the other mills downstream ceased operations for two days.

Analytical Method

The method adopted for this study was the oxygen consumed determination, essentially as outlined in "Standard Methods" (1). Potassium permanganate (1.0 ml. equivalent to 1.0 mg. of available oxygen) in acid solution was added to the river water at room temperature until a 3-min. endpoint was obtained, excess reagent was then added and digested in a boiling water bath for 30 minutes. A small excess of ammonium oxalate solution was then added and the analysis completed with $KMnO_4$ to react with the excess oxalate.

The cold permanganate values are a measure of the oxygen consuming power of the sulfites, sulfides, nitrites

and other readily oxidizable constituents. The hot permanganate data record the oxygen consuming power of the organic constituents present in the water. The values obtained are not absolute, but consistent and duplicatable values were readily obtained by the four cooperating groups of chemists. To ensure comparable results, detailed instructions based on numerous runs with Androscoggin River water were given to each group of analysts.

The 500-ml. samples were taken by rapidly sinking a weighted bottle to a depth of 5 ft. in the river and 10 ft. in the pond, at locations showing the greatest movement of water.

The weather was favorable during the period of sampling. Rainfall was infrequent and light except for a few days toward the end of the test period in Lewiston. One result of the low precipitation was a fairly uniform river flow, with few rapid increases or decreases.

Berlin, N. H. Area

The water from the upland storage basin arrives at Berlin, N. H. (Station 1) practically uncontaminated with sewage or industrial wastes. The oxidizable matter present in the water is that incident to a heavily forested drainage area. Five-day B.O.D. values seldom exceed 1.0 p.p.m., and were less than 0.5 p.p.m. during the test period. Dissolved oxygen averaged 7.4 p.p.m. Oxygen consumed from potassium permanganate (O.C.P.) averaged 7.2 p.p.m. when the dilute permanganate solution was employed; the stronger solution used in all other de-

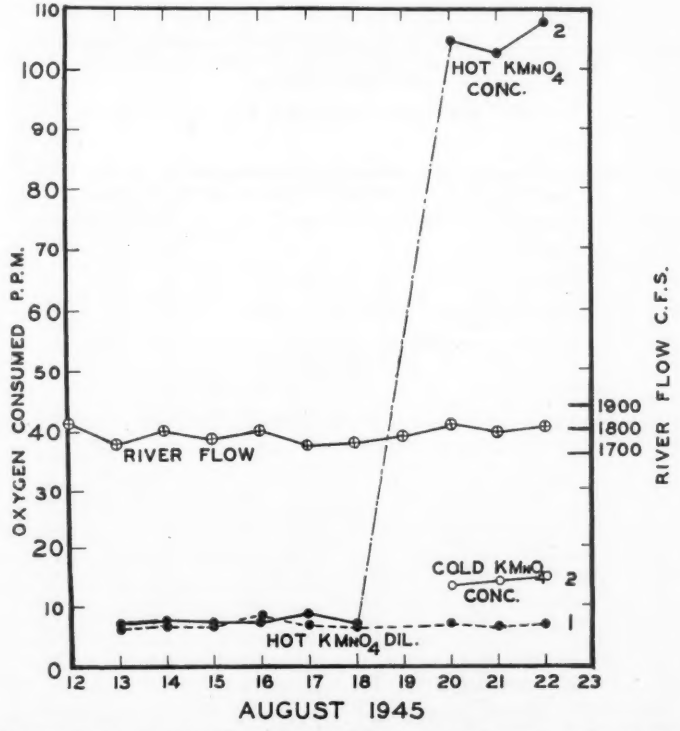

FIGURE 2.—Berlin, N. H. data. Dashed line represents results at Station 1, cold $KMnO_4$ data omitted. Solid line denotes Station 2.

terminations gave slightly higher values. During the shut-down period of August 12, 8:00 A.M. to August 20, 12:01 A.M. the river water arrived at "Cross-Power" (Station 2) polluted only with the untreated Berlin (pop. 18,000) sewage. The O.C.P. values (Figure 2) averaged an increase of only 1.0 p.p.m. above those obtained at Station 1. With the resumption of mill operations, the O.C.P. values rose rapidly to a total of 119 p.p.m.

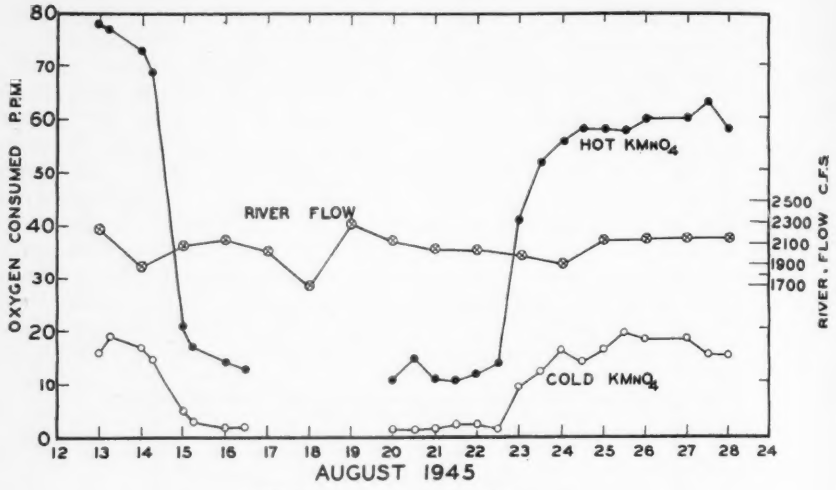

FIGURE 3.—Rumford, Me. data.

TABLE I.—Oxygen Consumed from Potassium Permanganate at Station 1 (Bell's Icehouse) and Station 2 (Cross-Power) in the Berlin, N. H., Area[1]

Station 1 (Bell's Icehouse)				Station 2 (Cross-Power)			
Date	Cold Titration (p.p.m.)	Hot Titration (p.p.m.)	Total (p.p.m.)	Date	Cold Titration (p.p.m.)	Hot Titration (p.p.m.)	Total (p.p.m.)
Method 1							
—	—	—	—	Aug. 20	13.8	105.0	118.8
—	—	—	—	21	14.0	103.3	117.3
—	—	—	—	22	15.0	108.5	123.5
Method 2							
Aug. 13	0.4	6.5	6.9	Aug. 13	0.1	7.4	7.5
14	0.4	7.4	7.8	14	0.1	8.0	8.1
15	0.5	7.3	7.8	15	0.5	7.8	8.3
16	0.3	8.2	8.5	16	0.5	7.8	8.3
17	0.4	7.4	7.8	17	1.0	8.3	9.3
18	0.5	7.4	7.9	18	0.6	7.5	8.1
20	0.5	7.4	7.9	—	—	—	—
21	0.5	6.7	7.2	—	—	—	—
22	0.5	7.0	7.5	—	—	—	—

[1] Production suspended from 8:00 A.M., August 12, until 12:01 A.M., August 20, 1945.

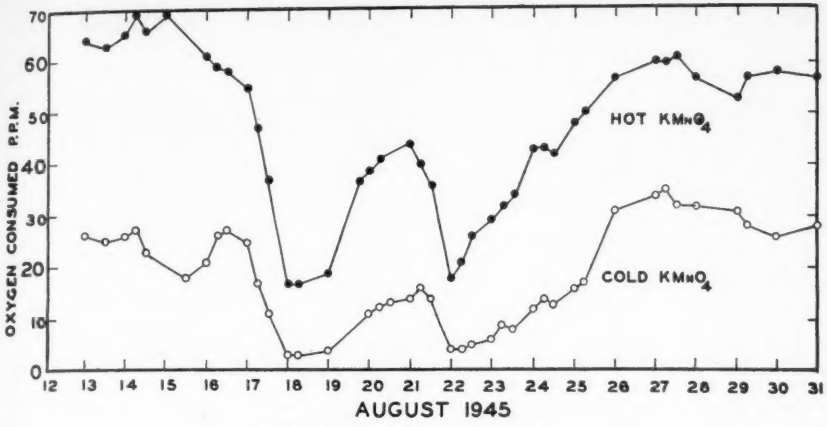

FIGURE 4.—Chisholm, Me. data.

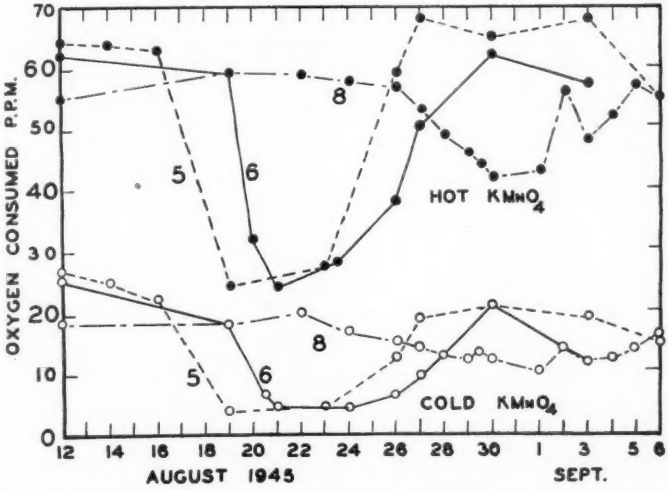

FIGURE 5.—North Turner Bridge data (Sta. 5), Turner Center Bridge data (Sta. 6), Gulf Island Dam data (Sta. 8).

Rumford, Me. Area

The organic pollution as measured by the hot permanganate test (Figure 3) had decreased from 108 p.p.m. at Station 2 to 76 p.p.m. at Virginia Bridge, Rumford (Station 3), a distance of 51 miles. The cold permanganate values, however, increased slightly during the passage between the two sampling stations. About 53 hours after the Berlin mills had ceased production, the O.C.P. values at Station 3 had fallen from a total of 94 to 84 p.p.m. Water samples taken the following morning analyzed 26 p.p.m. O.C.P. The low pollution load at Virginia Bridge extended over a period of 7.5 days, which approximates the length of the shut-down in mill operations. The resumption of production in Berlin increased the pollution load at Station 3 about 60 hours later. The return

TABLE II.—Oxygen Consumed from Potassium Permanganate at Station 3 (Virginia Bridge), Rumford, Me., Area

Date	Time	Cold Titration (p.p.m.)	Hot Titration (p.p.m.)	Total (p.p.m.)	River Flow—Rumford Gage[1] (c.f.s.)
Aug. 13	9:00 AM	16	78	94	2290
	1:00 PM	19	77	96	
14	8:00 AM	17	73	90	1900
	1:00 PM	15	69	84	
15	8:00 AM	5	21	26	2100
	1:00 PM	3	17	20	
16	8:00 AM	2	14	16	2190
	4:00 PM	2	13	15	
20	8:00 AM	1.5	11	12.5	2140
	5:00 PM	1.5	15	16.5	
21	8:00 AM	1.5	11	12.5	2090
	5:00 PM	2	11	13	
22	8:00 AM	2	12	14	2050
	5:00 PM	1.5	14	15.5	
23	8:00 AM	9	41	50	1990
	5:00 PM	12	52	64	
24	8:00 AM	16	56	72	1900
	5:00 PM	14	58.5	72.5	
25	8:00 AM	16	58.5	74.5	2160
	5:00 PM	19.5	58	77.5	
26	8:00 AM	18	60	78	2160
27	8:00 AM	18.5	60	78.5	2160
	5:00 PM	15	63.5	78.5	
28	8:00 AM	15	58.5	73.5	2170

[1] River flow on Aug. 17 was 2,060 c.f.s.; Aug. 18—1,720 c.f.s.; Aug. 19—2,300 c.f.s.

to normal pollution load was less rapid than the decrease, due to the fact that production in Berlin required a full day to return to normal volume, and probably, also to the initial high dissolved oxygen in the water just ahead of the pollution front, a condition which did not exist before the close-down. The hot permanganate values did not return during the test period to such high values as existed before the shut-down, whereas the cold permanganate values quickly became normal.

The 4.3 p.p.m. difference between the lowest O.C.P. values at Stations 2 and 3 represents the unoxidized sewage discharged from the towns of Gorham, N. H. (pop. 1,700) and Bethel, Maine (pop. 1,000), together with any compounds removed from the river benthal deposits.

Chisholm, Me. Area

The data obtained at Chisholm proved to be more valuable than had been expected due to the V-J Day shut-down at Rumford on August 15-16,

which coincided with part of the vacation period at Berlin. The decrease in the permanganate values (Figure 4) recorded at Station 4 between the 17th and 19th reflect the zero production at Berlin and Rumford. The rapid decrease in pollution load which occurred during the day of August 17 indicates that the river water which left Berlin August 12 arrived at Rumford August 15, at which time the mills there were closed, and flowed down to Chisholm without industrial wastes for about 48 hours. The lowest total O.C.P. values (20 p.p.m.) are almost 14 p.p.m. higher than the average for the unpolluted water at Station 1. The difference of 7.5 p.p.m. in O.C.P. between Stations 3 and 4 represent the unoxidized residues of the sewage from Rumford (pop. 8,500) and Mexico (pop. 4,000), plus any material leached from the benthal deposits in the stream.

The resumption of pulp production at Rumford on August 17 and 18, followed by a suspension on Sunday the 19th, is reflected in the analytical results obtained at Chisholm. The decrease of pollution load due to the Sunday holiday was about the same magnitude as that during the V-J Day shut-down, but of shorter duration. The period of reduced pollution at Station 4 was about 7.5 days, and approximates that of the shut-down at Berlin.

Androscoggin Pond Region

Sampling stations were located at North Turner Bridge (No. 5), Turner Center Bridge (No. 6), and Gulf Island Dam (No. 8).

The storage pond is that area covered by river water extending from the Rips 0.1 mile south of North Turner Bridge to Gulf Island Dam, a distance of 14.5 miles. Turner Center Bridge is located 7 miles south of North Turner Bridge, and crosses the pond at its narrowest point. The flooded area between the two bridges is comparatively narrow and contains about 20 per cent of the total storage water.

TABLE III.—Oxygen Consumed from Potassium Permanganate Results at Station 4, Chisholm, Me., Area

Date	Time	Cold Titration (p.p.m.)	Hot Titration (p.p.m.)	Total (p.p.m.)
Aug. 13	1:45 PM	26	64	90
	4:30 PM	25	63	88
14	10:00 AM	26	65	91
	1:00 PM	27	69	96
	3:00 PM	23	66	89
15	8:30 PM	18	69	87
16	8:00 PM	21	61	82
	1:15 PM	26	59	85
	3:45 PM	27	58	85
17	7:45 AM	25	55	80
	11:35 AM	17	47	64
	3:30 PM	11	37	48
18	7:30 AM	3	17	20
	10:20 AM	3	17	20
19	9:00 AM	4	19	23
20	8:00 AM	11	37	48
	1:00 PM	12	39	51
	3:30 PM	13	41	54
21	7:30 AM	14	44	58
	11:45 AM	16	40	56
	3:45 PM	14	36	50
22	8:30 AM	4	18	22
	11:45 AM	4	21	25
	3:34 PM	5	26	31
23	7:30 AM	6	29	35
	11:30 AM	9	32	41
	3:30 PM	8	34	42
24	7:45 AM	12	43	55
	11:45 AM	14	43	57
	3:30 PM	13	42	55
25	7:30 AM	16	48	64
	10:30 AM	17	50	67
26	9:00 AM	31	57	88
27	7:45 AM	34	60	94
	11:45 AM	35	60	95
	3:30 PM	32	61	93
28	8:10 AM	32	57	89
29	7:45 AM	31	53	84
	3:45 PM	28	57	85
30	7:30 AM	26	58	84
31	7:30 AM	28	57	85

Limited data (Figure 5) indicate that under normal conditions the O.C.P. values at Station 6 were only slightly lower than those obtained at Station 5. The relatively unpolluted river water arrived at North Turner Bridge some time after 10:00 A.M., August 16 and before 5:00 P.M., August 19. However, the low pollution front arrived at Turner Center Bridge a few hours after 5:30 P.M., August 19. If the slope of the plot of data at this station is applied to North Turner Bridge graph, it appears that the low pollution water arrived there during the evening of August 17. Volumetric displacement calculations made recently indicate that this time of arrival is substantially correct.

The time of passage for the 7 miles between the two bridges was approximately 48 hours under the conditions of flow then existing, 2,100 c.f.s.

Low pollution water arrived at the

TABLE IV.—Oxygen Consumed from Potassium Permanganate Results at Stations 5, 6 and 8—Androscoggin Pond Region

Station No.	Date	Time	Cold Titration (p.p.m.)	Hot Titration (p.p.m.)	Total (p.p.m.)
	Aug. 12	5:00 PM	27	64	91
	14	5:30 PM	25	64	89
	16	10:00 AM	22	63	85
	19	5:00 PM	4	24	28
	23	10:00 AM	4	27	31
5	26	11:30 AM	12	59	71
	27	2:30 PM	19	68	87
	30	9:00 AM	21	65	86
	Sept. 3	9:00 AM	19	68	87
	6	9:30 AM	15	55	70
	Aug. 12	4:30 PM	25	62	87
	19	5:30 PM	18	59	77
	20	3:00 PM	6	32	38
	21	2:30 PM	4	24	28
6	24	5:30 PM	4	28	32
	26	11:00 AM	6	38	44
	27	3:00 PM	9	50	59
	30	10:00 AM	21	62	83
	Sept. 3	8:30 AM	12	57	69
	Aug. 12	10:30 AM	18	55	73
	19	4:00 PM	18	59	77
	22	2:00 PM	20	59	79
	24	7:00 PM	17	58	75
	26	2:30 PM	15	57	72
	27	5:30 PM	14	53	67
	28	5:00 PM	13	49	62
	29	8:30 AM	12	46	58
8		4:00 PM	13	44	57
	30	12:00 NOON	12	42	54
	Sept. 1	10:00 AM	10	43	53
	2	10:00 AM	14	56	70
	3	10:00 AM	12	48	60
	4	9:30 AM	12	52	64
	5	9:00 AM	14	57	71
	6	8:30 AM	16	55	71

Gulf Island Dam at the southern end of the pond about 5:00 P.M., August 27. The O.C.P. decreased slowly but consistently to a low of 53 p.p.m. The return to normal pollution load was more rapid due to heavy rainfall upstream with a marked increase in stream flow. The temporary small decrease of pollution content on September 3 was probably due to the local rains and run-off of the previous days.

Surveys of Southern Half of Pond

The southern portion of the pond, which is situated between Turner Center Bridge and Gulf Island Dam, contains 80 per cent of the total storage water. The power company's operations at the dam, based on a drawdown Monday through Friday and fill over Saturday and Sunday, probably accentuates the by-passing of some of the large bays. The greatest depths are about 70 ft. and are in the area extending 2 miles north of the dam. Surface sludge conditions and the production of gas indicate the presence of active benthal deposits of cellulose origin.

Surveys were made by boat on August 24, 27, and 30 in the southern portion of the pond, and samples were taken approximately at 1-mile intervals. The objectives of these surveys (Figure 6) were to locate the low pollution front and, in case of extensive diffusion, to determine the dilution gradient.

The first survey made on August 24 revealed that low pollution water (O.C.P. 32 p.p.m.) was still passing under Turner Center Bridge, that a gradient existed to a point 2 miles south, then a constant O.C.P. of 49 p.p.m. for about 1.5 miles, then a gradient to the dam where normal values of 75 p.p.m. were obtained.

The second survey was made 3 days later. The high pollution water front resulting from the resumption of production of pulp had passed North Turner Bridge, and the O.C.P. values were back to normal. An increase of 15 p.p.m. O.C.P. had occurred at Turner Center Bridge, and the lowest values were obtained from water sampled about 2.2 miles south of the bridge. From this position to the dam the concentration of oxidizable com-

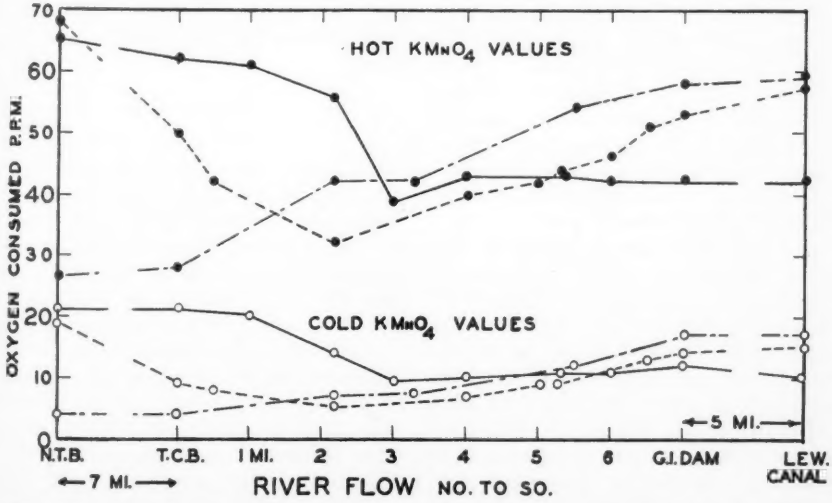

FIGURE 6.—Androscoggin Pond surveys; August 24 survey represented by short-long dash, August 27 survey by short dash, and August 20 survey by solid line.

TABLE V.—Oxygen Consumed from Potassium Permanganate Results—Androscoggin Pond Surveys

Date	Station	Time	Cold Titration (p.p.m.)	Hot Titration (p.p.m.)	Total (p.p.m.)
Aug. 24	North Turner Bridge	10:00 AM	4	27	31
	Turner Center Bridge	5:35 PM	4	28	32
	2.2 miles S. of T.C.B.	6:00 PM	7	42	49
	3.25 miles S. of T.C.B.	6:15 PM	8	42	50
	5.5 miles S. of T.C.B.	6:40 PM	12	54	66
	Gulf Island Dam	6:55 PM	17	58	75
	Lewiston	8:00 AM	17	59	76
Aug. 27	North Turner Bridge	2:30 PM	19	68	87
	Turner Center Bridge	3:00 PM	9	50	59
	0.5 mile S. of T.C.B.	3:20 PM	8	42	50
	2.2 miles S. of T.C.B.	3:40 PM	6	32	38
	4.0 miles S. of T.C.B.	4:00 PM	7	40	47
	5.0 miles S. of T.C.B.	4:20 PM	9	42	51
	5.25 miles S. of T.C.B.	4:30 PM	9	44	53
	6.0 miles S. of T.C.B.	4:45 PM	11	46	57
	6.5 miles S. of T.C.B.	5:05 PM	13	51	64
	Gulf Island Dam	5:25 PM	14	53	67
	Lewiston	8:00 PM	15	57	72
Aug. 30	North Turner Bridge	9:00 AM	21	65	86
	Turner Center Bridge	10:00 AM	21	62	83
	1.0 mile S. of T.C.B.	10.45 AM	20	61	81
	2.2 miles S. of T.C.B.	11:00 AM	14	56	70
	3.0 miles S. of T.C.B.	11:15 AM	9	39	48
	4.0 miles S. of T.C.B.	11:25 AM	10	43	53
	5.25 miles S. of T.C.B.	11:35 AM	11	43	54
	6.0 miles S. of T.C.B.	11:50 AM	11	42	53
	Gulf Island Dam	12:00 NOON	12	42	54
	Lewiston	8:00 AM	10	42	52

pounds increased to reach almost the same magnitude as existed 3 days earlier. Subsequent data proved that this small decrease in O.C.P. was the beginning of the decline in pollution load, and that the low pollution load would survive but would be modified by passage through the pond.

On the third survey, made on August 30, normal O.C.P. values were obtained to a point one mile south of Turner Center Bridge. Over the next 1.25 miles, a decrease of 11 p.p.m. O.C.P. was recorded, then a sharp decrease to a low of 48 p.p.m. at Mile 3.0 south of the bridge. A slight increase of 5 p.p.m. was obtained at Mile 4.0, then practically constant O.C.P. values of about 53 p.p.m. existed not only to the dam, Mile 7.0, but to Lewiston (Station 9) 4.8 miles south of the dam.

Lewiston Area

Water from the pond, after passing Gulf Island Dam, enters another storage area of about 200 million cu. ft. created by the Deer Rips Dam situated 1.5 miles downstream, then on to the Lewiston Falls. Under normal flow conditions the water is not allowed to pass over the Lewiston Dam and Falls, but is diverted into the industrial canal system which passes through the center of the manufacturing district and in very close proximity to the retail shopping center and some residential areas. This is important to the odor problem.

The majority of the samples were taken at Station 9, located about 0.3

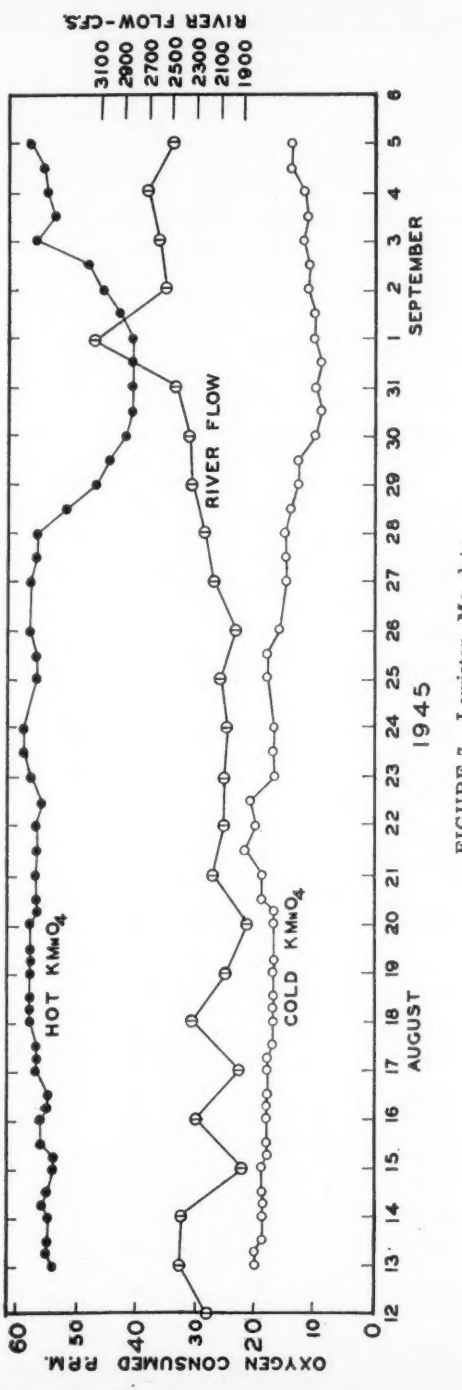

FIGURE 7.—Lewiston, Me. data.

TABLE VI.—Oxygen Consumed from Potassium Permanganate Results at Station 9 (Lewiston, Me.)

Date	Time	Cold Titration (p.p.m.)	Hot Titration (p.p.m.)	Total (p.p.m.)	River Flow (c.f.s.)
Aug. 17	8:00 AM	18	57	75	1940
	8:00 PM	17	57	74	
18	8:00 AM	17	58	75	2330
	8:00 PM	17	58	75	
19	8:00 AM	17	58	75	2070
	2:00 PM	17	58	75	
20	8:00 AM	17	58	75	1890
	4:00 PM	17	57	74	
	8:00 PM	19	57	76	
21	8:00 AM	19	57	76	2180
	7:00 PM	22	57	79	
22	8:00 AM	20	57	79	2080
	8:00 PM	21	56	77	
23	8:00 AM	17	58	75	2080
	8:00 PM	17	59	76	
24	8:00 AM	17	59	76	2020
25	8:00 AM	18	57	75	2100
	8:00 PM	18	57	75	
26	8:00 AM	16	58	74	1980
27	2:00 PM	15	58	73	2160
	8:00 PM	15	57	72	
28	8:00 AM	15	57	72	2210
	8:00 PM	14	52	66	
29	8:00 AM	13	47	60	2240
	2:30 PM	13	45	58	
30	8:00 AM	10	42	52	2270
	7:00 PM	9	41	50	
31	9:00 AM	10	41	51	2480
	7:00 PM	9	41	50	
Sept. 1	8:00 AM	10	41	51	3170
	6:00 PM	10	43	53	
2	9:00 AM	11	46	57	2590
	7:00 PM	11	48	59	
3	7:00 AM	12	57	69	2610
	7:00 PM	11	54	65	
4	8:30 AM	12	55	67	2730
	8:00 PM	14	56	70	
5	8:00 AM	14	58	72	2500

mile south of the Canal Gatehouse. Sampling and analyses were begun on August 13 and continued until September 5. Usually two samples were obtained, one about 8:00 A.M. and the other about 8:00 P.M. The evening samples were occasionally analyzed the next day; check determinations proved that overnight storage in completely filled bottles gave substantially the same O.C.P. results as freshly sampled water. The dissolved oxygen was less than 0.8 p.p.m.

The Lewiston data (Figure 7) show only small increases and decreases in the oxygen consumed during the period between August 13 and 28. The decrease in pollution load due to week-end shut-downs appears to be "lost" in the pond. The relatively constant O.C.P. values at the Lewiston station are due to the stabilizing effect of the slow passage through the Androscoggin and Deer Rips storage ponds.

During the day of August 28, the pollution load in the canal water began to decrease, and reached a low of 50 p.p.m. O.C.P. by 7:00 P.M. on August 30. The normal load had returned by 7:00 A.M., September 3. The duration of the lowered pollution load was about 36 hours less than that observed at the river stations north of the pond, due in part to diffusion effects in the pond and to the marked increase of river flow on September 1.

The shape of the oxygen consumed curve indicates a slow but appreciable decline in pollution and the minimum load extending over a period of about 60 hours. The two Rumford zero pollution load periods, which were readily indentifiable in the river (Table III), disappeared in the pond and no evidence of them was found in the water at Lewiston.

Time of Passage of Pollution

The time of passage of pollution in the Androscoggin River, based upon the oxygen consumed from potassium permanganate solution and upon the

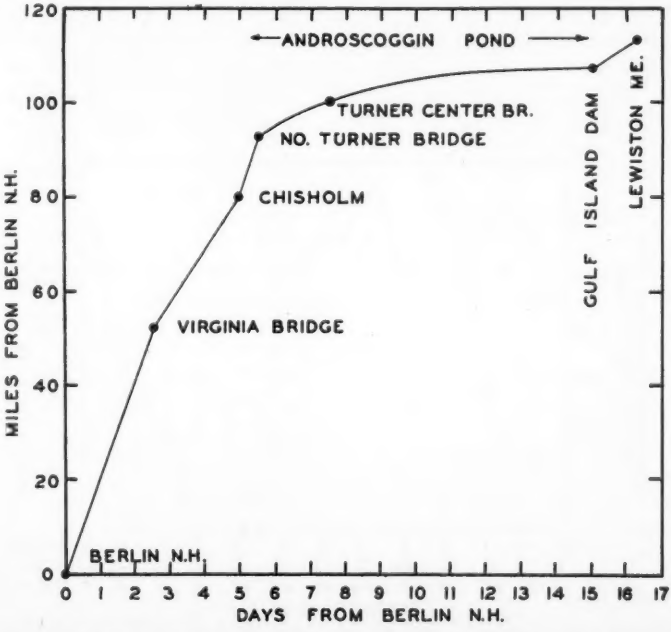

FIGURE 8.—Time of passage of pollution from Berlin, N. H. to Lewiston, Me.

TABLE VII.—Time of Passage of Pollution in the Androscoggin River and Pond—Aug. 12 to Sept. 6, 1945

Station No.	Location	Time (days)	Miles	Ave. River Flow for Test Period (c.f.s.)
1	Berlin, N. H.	0	0	1790
3	Virginia Bridge, Rumford, Me.	2.5	53	2080[1]
4	Chisholm, Me.	5	80	—
5	North Turner Bridge	5.5	93	—
6	Turner Center Bridge	7.5	100	—
8	Gulf Island Dam	15	107	2100
8	Lewiston, Me.	16.25	112	—

[1] Equal to 1.0 c.f.s. per square mile of drainage area.

river flow as recorded on the official gages, is summarized in Table VII and charted in Figure 8. The recorded times were calculated from the time difference between points where the pollution load began to drop rapidly. They are only valid, of course, for the rates of flow then existing. Normal summer average flows approximate 2,500 c.f.s. at Gulf Island Dam.

"Compensated Production-Pollution Load"

The time of passage data make possible the calculation of the position of the soluble waste products discharged into the river during a certain day at a given position hours or days later. Sulfite pulp production during the period of the test was correlated with the time of passage. The Berlin tonnage production on a given day was added to that produced in Rumford 3 days later and in Chisholm 5 days later. Figure 9 records the results obtained. The Lewiston dates are those on which the pollution passed or would have passed the city had the flow remained at about 2,100 c.f.s. The dates given are not corrected for the increase in flow from August 31 to September 2. The shape of this plot is very similar to that of the O.C.P. data for the Chisholm station (Figure 4); the relatively small production south of this point does not appreciably change the outline of the curve. The stabilizing effect of the slow passage of pollution through the pond is perhaps best illustrated by comparing Figures 7 and 4.

Comparison of Cold and Hot Permanganate Plots

The oxygen consumed from cold potassium permanganate solution is that used by inorganic compounds and any rapidly oxidizable organic matter while that removed during hot reaction is a measure of the organic constitu-

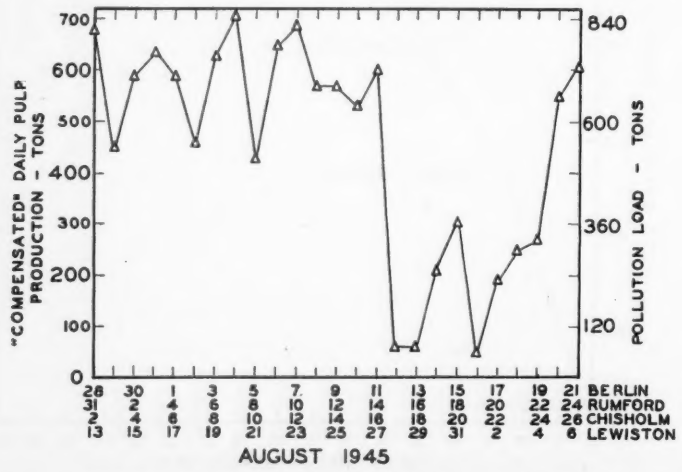

FIGURE 9.—"Compensated" production-pollution load.

TABLE VIII.—Comparison of Oxygen Consumed Results with D.O. and B.O.D. Data

Sampling Station	Date (1945)	O.C.P. Hot (p.p.m.)	D.O. (p.p.m.)	B.O.D. 5-day (p.p.m.)	Ratio B.O.D./O.C.P.
Berlin (No. 1)	Aug. 16	8.2	7.40	0.45	1:18
Rumford (No. 3)	Aug. 9	—	3.30	5.90	
	Aug. 16	14	5.70	2.65	1:5
	Aug. 23	41	4.05	2.95	1:14
North Turner Bridge (No. 6)	Aug. 16	63	4.40	7.27	1:9
	Aug. 23	27	4.30	3.90	1:7
	Aug. 30	65	2.85	4.72	1:14
Gulf Island Dam (No. 8)	Aug. 23	58	0.20	6.00	1:10
	Aug. 30	42	0.35	2.90	1:14
	Sept. 6	55	0.45	4.03	1:14
Lewiston (No. 9)	Aug. 16	56	0.80	8.32	1:7
	Aug. 23	58	0.30	6.23	1:12
	Aug. 30	42	0.75	3.10	1:14
	Sept. 6	58	0.95	5.52	1:15

ents oxidized under the conditions of the analysis. Comparison of two sets of plots reveal that while the contours of the curves are usually similar the cold values may increase or decrease somewhat while the hot values remain stationary. After the resumption of pulp production the cold permanganate values reached pre-shutdown levels at Rumford, exceeded them at Chisholm, but did not attain them at Lewiston. The hot permanganate values returned to previously existing levels except at Virginia Bridge. The increase in cold permanganate values in the river water sampled at Lewiston during August 20–22 coincides with an increase in the hydrogen sulfide content in the water and with the wide distribution of this gas in the air over the city. The hot permanganate values remained virtually constant.

Comparison of O.C.P. Values with Other Data

The water from thirteen sampling stations along the entire Androscoggin River system is analyzed each week. The B.O.D. and D.O. values obtained at some of these stations during the period of the time of passage tests are contained in Table VIII.

Generally the 5-day B.O.D. values decreased about 2 or 3 p.p.m. with the lowered pollution load, but the return to normal demands occurred a few days later than those of the O.C.P. As might be expected, a comparison of the data reveals an indefinite relation between the B.O.D. and O.C.P. Six of the twelve tests, however, show a ratio of about one to fourteen, but these results were obtained during the period of low contamination or just after the return to a normal pollution load.

The dissolved oxygen in the river north of the storage pond increased appreciably with the decreased pollution, but the increase at Gulf Island Dam was comparatively insignificant. This fact is not surprising in view of the slow passage through the pond and probable B.O.D. of the active benthal deposits.

Hot permanganate solutions oxidize more organic material and in a different manner than the biological and wet combustion processes accomplish in the water. However, the difference between the hot permanganate numbers corrected for D.O. obtained at two points in the river does represent a loss (or gain) of oxidizable material,

and to that extent measures the pollution oxidized (or added) between the two locations. Such information was frequently of considerable value, and it could be obtained rapidly without any knowledge of oxygenation and deoxygenation rates.

Summary

1. The method of determining oxygen consumed from potassium permanganate in acid solution by the soluble constituents present in water has been employed to obtain the times of passage of pollution in the Androscoggin River and Pond for a distance of 112 miles.

2. The "molecular" front was well defined in the river, but appreciable diffusion occurred in the slow passage through the storage pond.

3. The cold permanganate test was quite sensitive to small changes in the hydrogen sulfide content of the river water.

4. The differences between the hot permanagnate numbers of water obtained at two different points in the river has given a valuable index to the fate of a given pollution load.

5. Four different groups of chemists obtained satisfactory and comparable results for oxygen consumed from permanganate when using the standard method and observing the necessary precautions.

Acknowledgment

The analytical work of this project was conducted in the laboratories of the following companies: The Brown Company, for the Berlin, N. H. area; The Oxford Paper Company, for the Rumford, Me. region; and The International Paper Company, for the Chisholm, Me. area.

Water from the North Turner Bridge, Androscoggin Pond and Lewiston areas was tested in Hedge Laboratory, Bates College.

Appreciation is expressed to all whose efforts contributed to the completion of this assignment, and especially to R. A. Webber, E. L. Lamb and O. E. Anderson.

References

1. American Public Health Association, "Standard Methods for the Examination of Water and Sewage." Eighth Edition, 1943, Seventh printing.

2. Sanitary Water Board, Augusta, Me., "Investigation of the Pollution of the Androscoggin River and Remedial Measures" (1942).

MAKE YOUR HOTEL RESERVATIONS FOR THE DETROIT CONVENTION

The Hotel Statler at Detroit, headquarters for the Twenty-First Annual Meeting of the Federation in October, will be able to accommodate most of the out-of-town registrants. Some rooms will also be made available by the Book-Cadillac Hotel, located about three blocks from the Statler.

Requests for room reservations should be addressed directly to the hotel. Note that the technical program will open on Monday morning, October 18, and will close at noon on Thursday, October 21.

WRITE NOW FOR YOUR RESERVATIONS!

THE OPERATOR'S CORNER

CONDUCTED BY S. C. MARTIN

A JOB FOR EVERYBODY

At a Member Association meeting last spring, Lester T. Hagadorn, consulting engineer of Salina, Kansas, was requested to present a paper concerning problems of the small sewage plant operator. On polling his audience, Mr. Hagadorn discovered that only one sewage works operator was present. He promptly abandoned his prepared notes and proceeded to discuss the problem of interesting operators in professional meetings. Later, Mr. Hagadorn summarized these comments as follows:

"Economic conditions of the last few years have caused many operators of sewage treatment works to seek higher paying positions. These have been replaced by a great number of inexperienced operators. As a result, an unfortunate condition in plant operation has developed. When these replacement operators assumed their work, equipment operating information was missing. It either had been lost or had been taken by the old operators whose successors were thus deprived of important information.

"Everywhere operators are seeking needed information, particularly the type of information generally provided by manufacturers at the time equipment is installed. New operators seem to have difficulty in obtaining such information, partly because of a lack of knowledge of where it can be obtained, and partly because the pressure of new business has materially reduced the service activities of equipment companies.

"The apparent lack of interest in helping new operators has resulted in operators living somewhat as hermits, a condition that has been discussed quite generally but, apparently, about which nothing has been done. It is not a question of the operator wanting to live as a hermit, but because of his inability to obtain cooperation he has been forced to fight his battles alone. In many cases this has brought about very serious and disturbing situations.

"Some program or procedure should be set up so that needed information is made available to operators.

"Information sources available are as follows: bulletins from equipment companies on various processes of sewage treatment; equipment catalogs and operating instructions prepared by manufacturers; booklets on plant operation distributed by state health departments; bulletins distributed by university extension services; and many others. Most of this information is discussed in the various sewage works periodicals. . . .

"Unquestionably the Federation is very anxious to provide operators with all information possible that will improve sewage treatment works operation, and there is no doubt that operators are just as anxious to obtain such information. If some means could be devised to implement these mutual desires, certainly the field of sewage treatment would profit.

"The *Operator's Corner* of SEWAGE WORKS JOURNAL is one of the best means of assisting the operators with their problems. Also the JOURNAL feature, 'Bark from the Daily Log,' is of great help. Beneficial results from the information thus presented, however, will be achieved only when placed in the hands of the operators. This can be done only through membership in the Member Associations.

"In order for the Federation of Sewage Works Associations to achieve its goal, an

economical program must be instigated that will provide the missing link that will enable its good work actually to reach the hands of the operators."

Mr. Hagadorn has presented forcefully the plight of many sewage works operators. There can be no doubt but that literally hundreds of such men need and deserve assistance in solving daily problems and that many are eager to obtain help.

The problem is two-fold: first, an operator must have a deep personal interest in his work before he will try to improve himself through study and professional contacts; second, he must understand and appreciate how the Federation stands ready to help him.

Some operators have expressed the opinion that the JOURNAL is too "high powered." It must be remembered that the JOURNAL basically is a technical publication and for this reason cannot be read as one would read the *Saturday Evening Post*. Each issue of the JOURNAL contains many ideas and suggestions which the studious reader can adapt with profit to his own situation if he will read with an inquiring and thoughtful mind. The operator who is sincere in his desire to improve will make an effort to extract every particle of useful information from his reading.

Stimulation of individual improvement can best be developed by state health departments through their general supervision of plant operation and particularly by the contacts of their field engineers. These men meet operators as friends and advisers and earn their respect and confidence. Under such conditions the desire for improvement and professional growth can be awakened and encouraged. Consulting engineers, equipment representatives, and other operators are also in a position to help in this because of their personal contacts.

Real personal interest in a job can only be aroused and encouraged by an understanding friend or associate, if the challenge of the job has not been enough to do this. The Federation as an organization cannot provide this personal touch, but Federation members can. There is little direct motivation in a Federation letterhead, regardless of the warmth and persuasiveness of the message beneath it.

The task of acquainting operators with the advantages of Federation membership is likewise one which can be accomplished best on a person-to-person basis. One enthusiastic Federation member can do more in "selling" a fellow operator than can a whole series of headquarters or Member Association mail promotions.

Mr. Hagadorn has called for an "economical program . . . that will provide the missing link that will enable its (the Federation's) good work actually to reach the hands of the operators."

Such a program is available. It is economical, simple in application, and of proven effectiveness. Its basis is that each Federation member accept personal responsibility for encouraging the development of all sewage works men, particularly those new to the field, and for making the Federation's services known to those needing a helping hand.

When the majority of Federation members develop some measure of Mr. Hagadorn's interest in and concern for the sewage works men who need help, mutual aid among operators will increase, Member Associations will develop programs which will meet the needs of their regions, and the Federation will more perfectly fulfill its constitutional and moral responsibilities to all sewage works operators.

S. C. M.

VACUUM SLUDGE FILTRATION PRACTICES AT THE DETROIT SEWAGE TREATMENT PLANT

By Fred H. Burley

Engineer of Sewage Treatment, Detroit (Mich.) Sewage Treatment Plant

This short article is intended to give a summary of experience at Detroit in the use of the vacuum filtration process for the partial dewatering of primary treatment plant sludge prior to incineration.

Description of the Detroit Plant

The Detroit sewage treatment plant is operated by the Department of Water Supply and was placed in service in 1940. The city sewer system is mainly a combined system. The present connected population is approximately 2,300,000.

The sewage is pumped sufficiently high to flow by gravity through the bar racks, grit chambers, sedimentation tanks, effluent conduit, chlorine contact tank, and outfall tunnel to the Detroit River. Screenings are ground and returned to the intercepter. Grit is incinerated. The sludge recovered from the sedimentation tanks is filtered and incinerated in multiple-hearth incinerators. Approximately 25 per cent of the sludge is subjected to short-period digestion in a floating-cover heated tank.

Vacuum Filter Equipment

Equipment provided for conditioning and dewatering the sludge by vacuum filtration is as follows:

Eight Conkey-type vacuum filters, 500 sq. ft. each.
Three vacuum producers, rated 3,780 c.f.m. each.
Three rotary blowers, rated 1,200 c.f.m. each at 3 p.s.i.
Four filtrate pumps, rated 250 g.p.m. each.
One barometric leg, which is constructed adjacent to the intercepter and permits discontinuing the filtrate pumps during normal water levels.
Two 10,000-gal. rubber-lined tanks for ferric chloride storage.
Two ferric chloride pumps.
One 500-gal. rubber-lined auxiliary tank for diluted ferric chloride.
Four ferric chloride proportioneer pumps.
Four sludge conditioners equipped with sludge bucket elevators, paddle mixers, and piping to two vacuum filters each.
Four lime storage tanks, 60 tons capacity each. Two are retained for pebble lime, with feeders and slakers as stand-by. Two have been converted to liquid storage for the use of carbide process waste lime slurry.
Four lime slurry feeding devices with quick-acting valves actuated by the bucket elevator shaft.

Operation of Sludge Filters

The two main objectives of the sludge filter department are economical operation and coordination with other departments of the plant. The former is concerned largely with the careful selection and control of chemicals and supplies, and vigilant avoidance of waste. This is taken up in greater detail later in this article. The latter is apparent to anyone familiar with plant control, but it necessitates more immediate attention in this plant than is commonly necessary in most primary treatment plants.

Sludge recovered by the sedimentation tanks must be processed and incinerated as received since no storage facilities are provided. Sufficient sludge to maintain a high rate of feed to the digester is necessary to provide gas to heat the plant during cold

winter weather. Gas for the gas engine-driven 240-kva. generator is considered secondary at that time. The incinerator feed requires careful regulation within narrow limits. Part of this feed is wet grit, and the filter load has to be diminished when it is being burned.

Sludge Characteristics Affect Costs

Sludge delivered to the filter department may be raw sludge, digested sludge, or "mixed" sludge composed of raw and digested sludge. Test runs were made in August, 1946, to determine the effect of sludge selection on chemical cost at prices then prevailing. This study showed (Table I) raw sludge filtration to be the cheapest, mixed sludge the next, and digested sludge the most expensive. When the effect of volume reduction of sludge during digestion is considered, it is found that only 79 per cent as much digested sludge has to be filtered as raw sludge. This volume reduction, however, does not compensate for the higher cost of direct filtration of digested sludge.

Further checks have been made with variations in sludge volatile matter, and subsequent chemical cost increases considered. The cost relationship was found to remain valid. At present it is the practice to resettle the digested sludge by sending it to the sedimentation tanks during the greater part of the year. The sludge recovered filters substantially the same as raw sludge. During the coldest winter months it is found beneficial to draw the digested sludge directly to the filter department. There its temperature and other properties aid filtration of the difficult primary "winter sludge," which has a tendency to quickly "scab" over the filter.

The delivery of the bucket elevator on each sludge conditioner is calibrated and counters are read hourly. The difference in counter reading, multiplied by the bucket elevator delivery constant, multiplied by the sludge concentration in pounds dry solids per gallon (determined by the laboratory), equals the dry sewage solids for the hour.

Sludge Conditioning Chemicals

Ferric chloride is delivered at the plant in rubber-lined tank cars. The present cost is $56.80 per ton, or nearly double the 1946 cost. The ferric chloride has a concentration of approximately 4.8 lb. per gal. as received and stored. As needed, it is pumped to an

TABLE I.—Comparative Data on Separate Filtration of Mixed, Raw, and Digested Sludge at the Detroit, Mich. Sewage Treatment Plant, August—1946

Type of Sludge and Period	Bicarbonate Alkalinity (p.p.m.)	Sludge to Filters		Dry Solids Filtered (tons)	Chemicals Used				Filter Yield (lb./sq. ft./hr.)	Sludge Cake, Per Cent Solids	Cost of Chemicals* (per ton sludge filtered)
		Per Cent			Tons		Per Cent				
		Solids	Volatile		CaO	$FeCl_3$	CaO	$FeCl_3$			
Mixed 1 to 12	1190	7.39	61.2	1654	111.8	41.5	6.76	2.51	6.34	30.6	$1.44 ($1.83)**
Raw 13 to 31	880	9.13	56.8	2527	142.1	55.9	5.62	2.21	7.30	32.3	$1.24 ($1.59)**
Digested 13 to 31	2840	7.16	48.4	561	59.3	13.1	10.56	2.33	6.19	33.2	$1.81 ($1.96)**

* Costs based on lime at $11.00 per ton (100 per cent CaO) and $FeCl_3$ at $1.40 per cwt.
** Costs for first part of 1948.

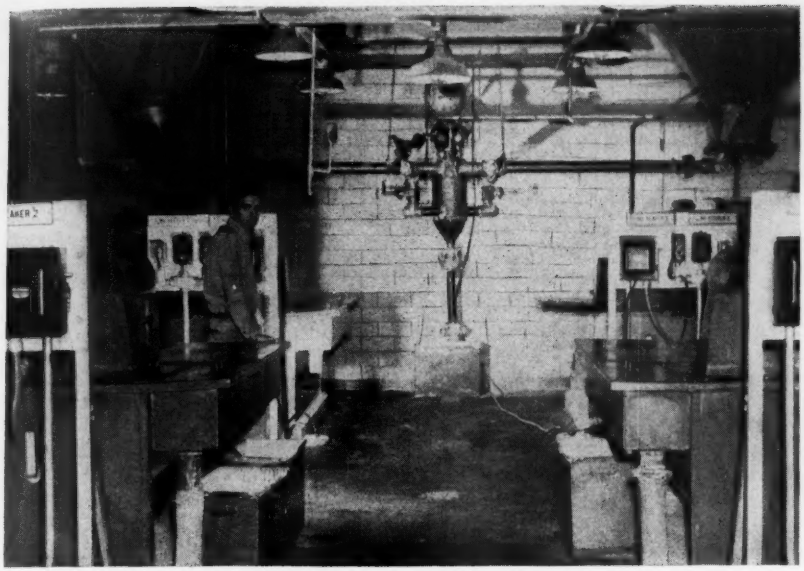

FIGURE 1.—Chemical room, Detroit sewage treatment plant. Lime slakers in foreground retained for standby use with pebble lime. Slakers in background disconnected and bins above them converted to carbide waste lime slurry storage. Note sediment trap, bypass, and cleaning connections of gravity flow system.

auxiliary tank and diluted at the same time.

Automatic Ferric Chloride Dilution

A successful means of automatic dilution of ferric chloride was installed in 1946. A water line is equipped with a pressure regulator so that constant pressure is maintained. A solenoid valve on this line opens at the same time the ferric chloride pump is switched on. A timing device shuts off both the pump and valve at a predetermined time interval.

The diluted ferric chloride, at a constant concentration of 1.7 lb. per gal., flows to the proportioner which is located at each conditioner. The proportioneers are of the adjustable stroke type and are operated by the bucket elevator shaft. The diluted ferric chloride is checked by a hydrometer to determine the exact concentration. The volume per stroke of the proportioneers is measured by a graduated cylinder held under the discharge for three strokes. These observations, together with the bucket elevator counter reading, provide means of computing the amount of ferric chloride used during the hour.

The ferric chloride storage tanks are also inventoried at the end of each shift to compute the dosage for the shift. The chemical dosages, ferric chloride and lime, are the dry weight of chemicals used divided by the weight of dry sewage solids processed, expressed as per cent.

Waste Lime Slurry Used

The use of waste lime slurry resulting from the production of acetylene gas from calcium carbide was started on a half-plant scale in November, 1946, and has been described previously in detail (1). At the present time, waste lime slurry is used almost entirely. The slurry is concentrated at the carbide plant and transported

in a 3,400-gal. semi-trailer tank. It is pumped to the two 12,000-gal. storage tanks and fed by gravity to the sludge conditioners (Figure 1).

The cost of pebble lime on CaO basis is approximately $13.00 per ton, or nearly double the cost of the delivered carbide waste slurry. The original plant layout provided for one slaker to serve each sludge conditioner. Milk of lime lines were revised so that when using pebble lime two or more sludge conditioners could be supplied by one slaker. This resulted in more economical dosage.

Sludge and Chemical Mixing

Mixing of the chemicals and sludge deserves careful attention as the process must be thoroughly done but not so vigorously as to break up the floc formed when the ferric chloride hydrolizes into ferric hydroxide. Experimentation with introducing the ferric chloride at various locations has determined that the optimum location is on the sludge line between the bucket elevator and the mixing tank. This provides for mixing prior to hydrolization. The lime is added near the inlet of the mixing chamber. Wooden paddles of triangular cross section are mounted on a variable-speed mixer shaft. The pH of the filtrate is a guide to effective lime dosage. With the use of pebble lime this was held below pH 11 as much as possible.

Vacuum Filter Operation

The sludge filter drums have decking divided into sections. These sections are connected by tubes to a valve head through which the vacuum is applied and the filtrate removed during the greater part of the drum revolution. The decking is provided with 432 supporting strips for the Monel-metal wire mesh. There are also 25 longitudinal hardwood strips dividing the various segments, and these are provided with a slot for ½-in. longitudinal ropes.

Placement of Filter Cloths

The filter cloth is placed over the wire mesh. Ropes are then placed on the cloth and the ropes driven into the grooves of the longitudinal hardwood dividing strips. For some years it has been the practice to place the rope in only every third strip (2). This has given an adequate seal between drum segments and has reduced mechanical wear of the cloth, saved rope, and lessened blinding of the cloth.

The cloth is then wired to the drum by wrapping it at the ends and along the entire drum length with a continuous wire spaced on a 3-in. pitch. The wire used is No. 11 bright basic, and serves very well for one use. Its price has increased from $3.50 per cwt. in July, 1945, to $4.80 per cwt. in July 1947. During the war the shortage of wire necessitated the purchase of some annealed wire. Due to breakage and other unfavorable characteristics, annealed wire was found inferior to the bright basic wire.

To date, it has been necessary to replace the wire mesh supporting strips on four filters. Bearings have been replaced on seven filters. Valve heads and plates have been removed and machined on all filters.

Lime Scale Removal

Lime scale formation makes it necessary to give each filter an acid bath every 4 to 6 months. This is done with the cloth removed. The sludge is removed from the pan and the wire mesh washed. About six carboys of commercial muriatic acid, with inhibitor, are emptied into the filter pan.

A portable acid pump (Figure 2), equipped with explosion-proof motor, has been built for circulating the acid through the valve head, tubing, decking, wire mesh, and filter pan. The pump suction line is connected to the clean out plate at the bottom of the

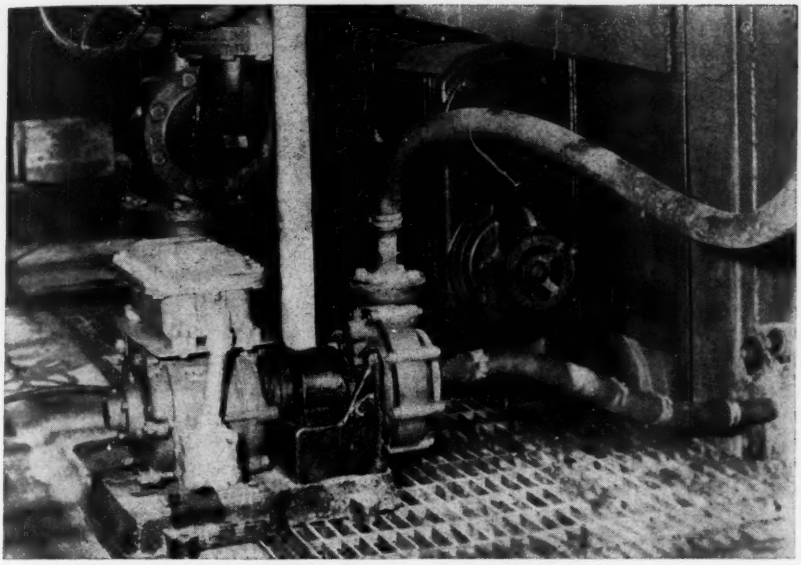

FIGURE 2.—Portable acid cleaning pump with explosion-proof motor. Suction line connected to cleanout plate at bottom of filter pan. Discharge line replaces air blow connection on the filter valve heads.

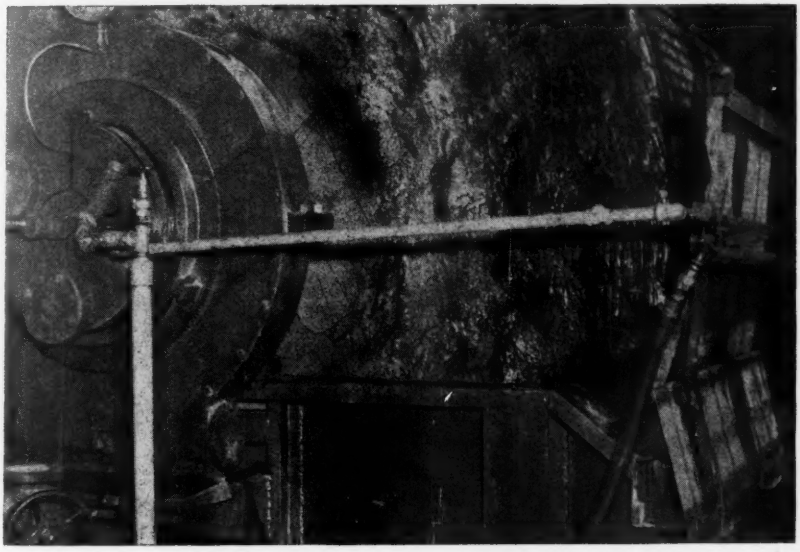

FIGURE 3.—Acid cleaning of filter. Discharge line from acid pump attached to piping which replaces air blow connection on filter valve heads. Vacuum connection replaced with blind flanges. Scraper plate removed and protection screen placed at level of normal air blow.

filter pan. The discharge line replaces the air blow connection on the filter valve heads (Figure 3). As far as can be determined, Mr. Cleon Oakes, plant supervisor, was the first to utilize this system.

From time to time the acid strength is checked by the laboratory staff. Frequently the acid bath requires 20 carboys of acid. This method is fairly effective in reducing carbonate scale. It was usually supplemented by a detergent bath and much brushing by hand to remove additional scale and grease.

At long intervals scale removal by tube and pipe cleaners is necessary to clear deposits in filter tubes, the filtrate and vacuum lines, and the 12-in. drain line to the barometric leg. Since the change-over to the use of carbide lime slurry, the deposits in the larger lines have been much less in quantity and are much easier to remove.

Gate valves in pipe lines carrying filtrate are rendered inoperative by lime deposits. This prevents isolation of parts of the system for the performance of maintenance work. It also fails to protect adequately the vacuum producers. Lubricated type plug valves, installed experimentally, have thus far proved more suitable than the gate valves, and further replacements have been scheduled.

Flannel Filter Cloths

Filter cloths now used are 10-oz. Canton flannel. This material has a nap and has proved less quick to "blind" with sludge, grease, and carbonate deposits than does a napless cloth. The cost has increased in the last 3 years from 29 to 48 cents per linear yard 34 in. wide. The cloths are sewed at the Detroit House of Correction at a fixed price per cloth.

Plastic Fliter Cloths

Samples of several plastic cloths have been tried. These were placed as 1 or 2-sq. ft. sections on a filter otherwise covered with Canton flannel. Specimens of the cake produced were taken by cutting out "cookies" of the sludge cake at the point of discharge. These specimens were then compared with the standard cloth sludge cake for comparative production. A record was also kept of the cloth "blinding," mechanical wear, and other observations.

The results have shown lower production by the plastic cloth almost from the first time the cloth was placed in service, and much earlier "blinding." Certain of the plastics examined under a magnifying glass did not show true "blinding" but a splitting of the threads into individual strands which obstructed the open spaces between threads. For the present at least, continued use of Canton flannel colths seems by far the most economical practice.

Filter Cloth Life

Filter cloth life is measured by two highly important yardsticks. The one most commonly recognized is that of hours of service obtainable from the cloth before mechaincal failure of the cloth by tearing results, or before complete "blinding" of the cloth occurs. The other important yardstick is the maximum economical life of the filter cloth, taking into consideration the investment in cloth and wire, the greater chemical dosage necessary to keep old cloths in service, and the decrease in production obtainable from an old cloth.

The relationship between maximum economical cloth life and hours of service is shown in Figure 4. The exact data will vary somewhat with costs of cloth, wire, and chemicals, and with the specific conditions at various plants. However, it is believed that the greatest filter cloth economy is obtainable by a study of these factors. After the "hours of service" has entered the long flat portion of the curve

"cost of production chemicals and cloth per ton dry solids" (Figure 4), it is undesirable to continue large increases in conditioning chemicals in order to maintain production. Present practice at Detroit is to use a filter cloth for 300 to 340 hours. No attempt is made to obtain 400 hours service from a cloth, as was done some years ago.

Variations in Sludge Cake Composition

The sludge cake as discharged from the vacuum filters has, on an annual average (1946–47), a solids content of 31.20 per cent, of which 55.95 per cent is volatile solids. This volatile content is sufficient to evaporate the moisture and sustain combustion of the sludge cake in the incinerators, with only occasional use of auxiliary fuel. It should be emphasized, however, that wide variations in moisture and volatile content occur in short periods of time, often in 8 hours or less.

The usual sequence of events is that during dry or continued freezing weather the sludge recovered by the sedimentation tanks gradually increases in volatile content. For example, the volatile content might increase from 61 per cent (1946–47 annual average) to 68 or 70 per cent, or even more (Figures 5 and 6). When storm water flow or thawing and surface run-off occurs, a much more concentrated sludge of lower volatile content results, and for a day or two the volatile content may drop to 42 per cent (Sept. 2, 3, 1947).

The lower volatile content sludge requires less chemicals for conditioning

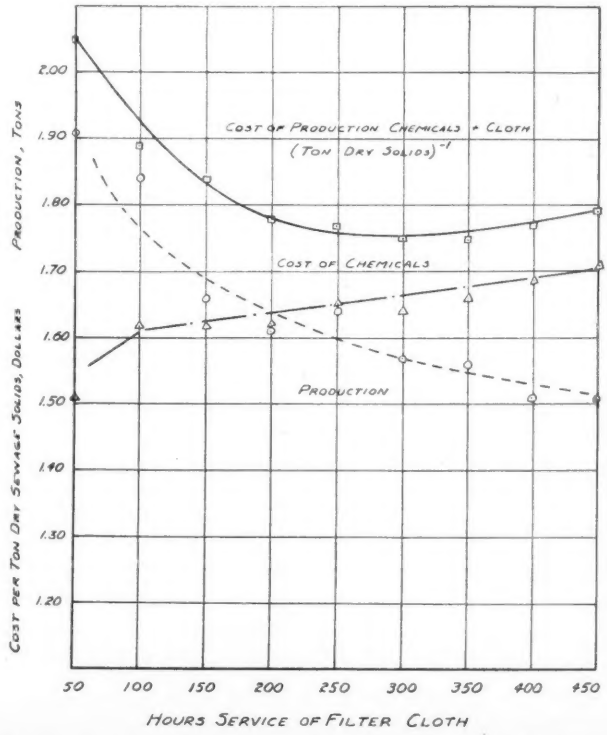

FIGURE 4.—Economical life of cloths on vacuum sludge filter.

(Figures 5 and 6), and the cost of chemicals may drop for a short period to 80 cents per ton of dry sewage solids. With the increase in volatile content, and resultant increase in conditioning chemicals, the cost of chemicals may rise to $1.80, or more, per ton of dry sewage solids. These cost figures are based on the present high cost of ferric chloride.

As a matter of achievement in keeping chemical dosage down, it is noteworthy that for 11 months of 1947 the ferric chloride dosage was less than the corresponding months in 1946, the exception being January, which is a variable month due to winter sludge. The chemical cost varied from $1.04 to $2.53 per ton of dry sewage solids conditioned, and was less than $1.40 during nine months of 1947.

Filter cake volatile content and moisture vary in the same direction, so that when the volatile content is high the moisture is high, and when it is low the moisture which must be evaporated in the incinerators is less.

Filter Drum Speed

Filter drum speed is important to filter cake moisture control. The original filter drives at Detroit had a minimum speed of 1 revolution in 7 minutes. During recent months a change in drive sprockets has made possible a minimum speed of 1 revolution in 11 minutes. This slower speed makes for a drier and more uniform

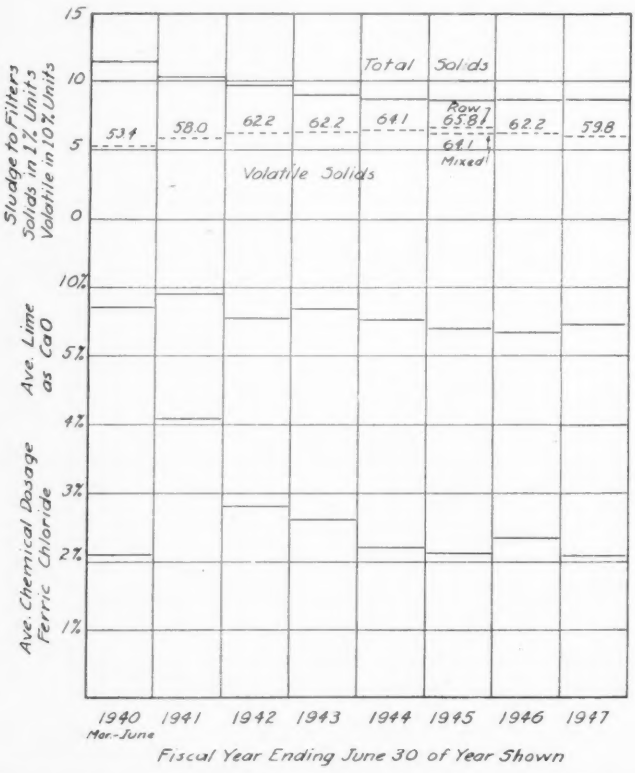

FIGURE 5.—Total solids, volatile solids, and chemical dosage of sludge to vacuum filters for 1940–47, incl.

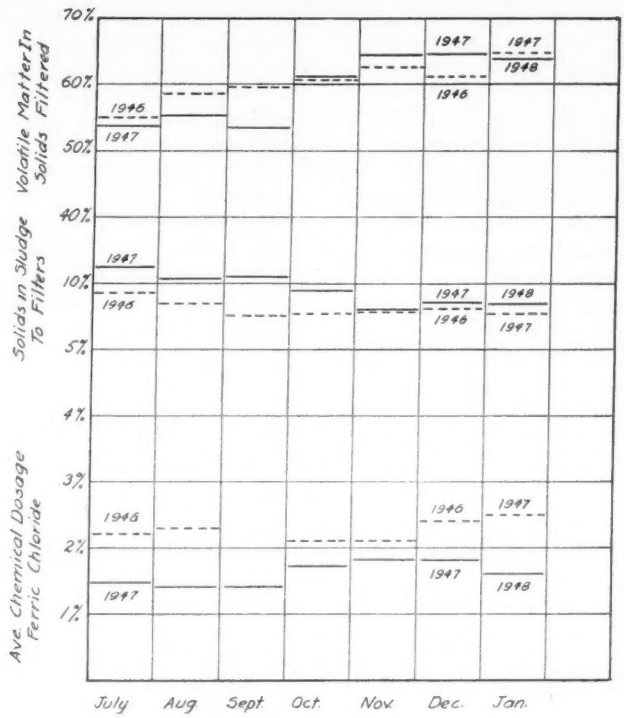

FIGURE 6.—Volatile matter and solids in sludge to vacuum filters, July–Feb. 1946–47 and 1947–48.

cake, although the filter yield is reduced by this change to 4.2 lb (dry sewage solids) per sq. ft. per hour, compared to the 1946–47 average of 5.9 pounds.

Filter Capacity

Six sludge filters are required for normal operation. This makes a drop of only 17 per cent in production when a filter is taken off for the wash scheduled for each filter every shift. The eight filters installed in the plant are barely adequate, in capacity, as six are normally on production, leaving only two out of service for cloth changes, acid baths, and maintenance.

Balancing of sludge solids handled is accomplished by comparing the dry sewage solids measured by the bucket elevator with the sludge cake weightometer reading. The weightometer quantity is multiplied by the solids content of the sludge to obtain dry weight. From this, the correction for chemicals is subtracted, or 1.3 times the CaO weight (3).

Economies Effected

The improvements, and resultant economies, which have been successfully introduced at Detroit are the result of the efforts of a number of members of the plant organization. The more important improvements producing economy and good production are:

Close control of chemicals
Use of dilute ferric chloride
Use of carbide waste lime slurry
Filter cloth washing at regular intervals

Acid washing of filter drums and mesh
Use of efficient pipe and tube cleaners
Use of raw sludge as much as possible
Mixing of digested sludge with the difficult "winter sludge"
Selection of economical cloth life
Weightometer check on solids; proper solids balancing
Inventory check and dosages computed for each shift
Daily chemical quantities adjusted to correspond to monthly stores inventory for monthly reports
Reduced filter drum speeds.

It will be noted in Figure 5 that the amount of ferric chloride required has decreased nearly every year since the start of operation. Lime usage has increased somewhat during recent months due to the use of low-cost "carbide lime" and the improvised feed devices used with it.

Figure 6 shows that the monthly average ferric chloride dosages for the past 7 months are lower than the previous corresponding months. Since a saving of 1.0 per cent of ferric chloride at the present rate of sludge processing, 4,500 tons dry sewage solids per month, amounts to 45.0 tons of ferric chloride at $56.80 per ton, or $2,556.00 monthly, it is apparent that the savings of 0.30, 0.60, 0.90 per cent are very much worthwhile.

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PLANT EFFLUENT USE AT FORT WAYNE

By Ralph A. Hoot
Superintendent, Fort Wayne (Ind.) Sewage Treatment Plant

In this day and age when in our national economy money is grandiosely referred to in terms of millions and billions, a $2,400 per year saving may not seem like a great amount. Nevertheless, even to a medium size sewage plant it represents a significant sum, especially when it can be accomplished at virtually no expense.

This is exactly what happened at the Fort Wayne sewage treatment works when Paul Brunner, plant chemist, came forward with the money-saving idea of using plant effluent instead of city water for general plant purposes.

In the design of the Fort Wayne plant the engineers provided for the use of city water for such operation and maintenance purposes as meter flushing, chlorinator feed, grease skimming, etc. The city water for these uses was supplied from a tower tank. Cross-connection of the city water supply and the tower tank system is avoided by use of an above-the-rim discharge inlet having a 3-in. air gap.

Also provided were two plant effluent pumps which were to supply water for grit washing and lawn sprinkling. Brunner's suggestion was to cross-connect the tower tank line and the plant effluent line and pump plant effluent into the tower tank system.

The necessary connection was made in November, 1943. Costs of city water for the 6 years the Fort Wayne plant has been in operation are as follows:

1941—$3,089.46
1942— 4,109.13
1943— 3,642.17
1944— 1,151.50
1945— 1,252.17
1946— 1,113.20

The use of plant effluent rather than city water for meter flushing, grease skimming, etc. effected a saving of over $7,300 for 3 years, an average of over $2,400 per year. This saving was accomplished at a cost of one 4-in. gate valve and one day's work by three of the plant men.

The moral of this story, of course, is more general utilization of plant effluent for sewage plant service. At Fort Wayne the effluent water system in addition to the tower tank system comprises: one 6-in. tide gate; a 4-ft. by 6-ft. by 6-ft. concrete screen box adjoining one of the final tanks; 270 ft. of 6-in. pipe; two 50 g.p.m., 50-lb. pressure pumps with 3-hp. motors; six 4-in. valves, and 100 ft. of 4-in. pipe.

No trouble has been experienced with the use of effluent water for meter flushing and chlorinator feed water supply. The effluent solids content has average 15 to 20 p.p.m. Not only has the effluent water been equally as satisfactory as city water, but for certain winter uses its use has been much more practicable since the 50° F. plant effluent is less subject to freezing than the 32° F. city water.

OPERATING EXPERIENCES AT TENAFLY, N. J.*

By J. Kenneth Adams

Superintendent, Tenafly (N. J.) Sewage Treatment Plant

Many interesting operation problems have been encountered at the Tenafly activated sludge plant during the years of its operation. A few of these will be briefly discussed with the hope that they may be interesting, informative, and helpful to other sewage works men.

Plant Design

The Tenafly plant design represents a considerable departure from that of the conventional activated sludge plant. In place of primary settling tanks, primary treatment is provided by coarse and fine screening. The fine screening is accomplished by a Tark screen. Secondary treatment is provided by activated sludge, the air being supplied through diffuser plates.

The plant is designed to handle 1.75 m.g.d. with a 5-hour detention period in the aerators. Following final settling, the clarifier effluent is further stabilized by passage through sand filter beds and is also chlorinated before discharge to the outlet stream which feeds an important public water supply reservoir.

The Tenafly plant has no sludge digesters. The waste activated sludge is conditioned by the addition of ferric chloride and then dewatered on vacuum filters. Flash drying in a Raymond dryer reduces the filter cake moisture content to about 10 per cent. The dried sludge is bagged and sold for fertilizer, as will be described later.

Saran Filter Piping

Conditioning of the raw activated sludge with ferric chloride prior to vacuum filtration results in the filtrate having a low pH of less than 5.0. With such a corrosive liquid more or less continuous trouble was experienced with leaks in the brass filter piping.

In August, 1944 the ¾-in. interior piping of one filter was replaced with Saran, a Dow Company plastic piping. In June, 1945, the interior piping of the other filter was also replaced with Saran. There has not been a single leak develop since then.

All 1½-in. exterior filter piping is

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* Presented at the 33rd Annual Meeting, New Jersey Sewage Works Association, Trenton, N. J., March 10–12, 1948.

now being replaced as needed. Saran and brass cost about the same at the present time.

Pump Clogging

One of the outlying pumping stations on the sewer system has given maintenance trouble for years because of the frequent clogging of the 4-in pumps. Before reaching the pump suctions, the sewage passed through a bar screen having 1½-in. openings. Replacement of this screen with a screen having ¾-in. openings has resulted in a practical elimination of all pump clogging trouble.

Fine Screen Brushes

The Tenafly plant has one of the relatively few sewage fine screen installations. This fine screen is a Tark screen and consists of a drum slowly revolving around a horizontal axis, the curved surface of the drum forming the screening area. The raw sewage enters through the descending side of the screen, leaving the solids on the outside, and discharges through the end of the drum. The screen is almost entirely submerged in the sewage and the screenings remain on the drum until they reach the top, where they are brushed off.

Originally the brushes required rebristling every year. Hog bristles from China or Siberia were used for replacement. Five years ago it was decided to use nylon bristles instead of the hog bristles and it has been found that the nylon bristles give four to five times more service than hog bristles.

When this change was first made the replacement cost for nylon was about $66 per brush, as compared with $45 for the hog bristles. No recent quotation on the old style of bristle has been obtained, but it is worth noting that there has been an increase of only 3 per cent in the cost of nylon bristles in the last 5 years.

Effluent Utilization

Two Wallace and Tiernan chlorinators are in use at Tenafly. One operates continuously for effluent disinfection and the other is used only occasionally when the return sludge is chlorinated to improve the sludge index. Several years ago it was decided to use the chlorinated plant effluent as a source of water supply for the chlorinators so that the water bills could be reduced. A Westro pump having a capacity of 19 g.p.m. at 80-ft. head was used to supply the final effluent to the chlorinators.

From a cost standpoint, the results were very satisfactory in reducing the paid water consumption 50 to 75 per cent, depending on whether one or two chlorinators were in use. Some operation difficulty has been encountered, however, which, while not serious, is annoying at times. It is hard to keep the chlorinators clean. Frequent cleaning of the several chlorinator strainers is necessary due to grease and small solid particles that are drawn into the effluent supply line at the chlorine dosing chamber.

Sludge Line Clogging

Another operating problem has been the occasional clogging of the 4-in. return sludge line from the bottom of the final settling tank. Sometimes the obstructions could be removed with sewer rods, but often this was impossible owing to bends in the lines. Occasionally it was necessary to use an auxiliary pump to remove the 30,000 gal. of water and sludge in the final tank so that the rods could be used from the inside of the tank.

This recurring clogging nuisance has been largely overcome by tapping a hole for a ¼-in. nipple in the sludge line just back of the valve regulating the rate of sludge return. With this valve closed, air pressure of 50 to 60 lb. per sq. in. is applied at the nipple. This moves the pipe stoppage immediately, producing a violent agitation in

the clarifier. After a few minutes of the air treatment the line is in working order again.

Fertilizer Production

A Raymond flash-dryer is used at the Tenafly plant to dry dewatered sludge from the Oliver vacuum filters. Originally, it was intended to burn the dewatered sludge in the garbage incinerator, which was erected at the same time. The sludge was soon found to be too valuable to be disposed of in this way.

When drying equipment was installed, a trade name for the dried sludge—Tenafly Soil Food—was registered and the sludge marketed with a guaranteed nitrogen content of 5 per cent and total phosphoric acid content of 3 per cent.

Revenue from the sale of dried sludge has increased every year, amounting to $4,673 last year, at $30 per ton. About $500 worth of fuel oil and $200 for paper bags should be charged against this revenue, leaving nearly $4,000 net income from the sale of sludge. No charge for labor or chemicals is included because these costs would be approximately the same for other types of sludge disposal.

Air Lifts

Experience at Tenafly indicates that the wider use of air lifts is warranted. When the plant was enlarged in 1940 the design engineer included an air lift for elevating the sludge drawn from the final tanks to a level from which it can be recirculated through the aeration tanks without flowing back to the wet well to be pumped with the raw sewage.

The air lift installed consists of two vertical concentric pipes, one 8 in. and the other 2 in. in diameter. In the larger pipe the sludge rises to its natural static level, and through the smaller one air at about 6 p.s.i. pressure is introduced at a certain predetermined level below the surface.

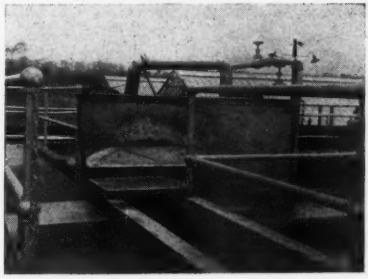

FIGURE 1.—View of return sludge measuring box showing control valve for air lift and vent pipe for covered portion of sludge box.

This causes the sludge to rise in the outer pipe and discharge into the sludge measuring box (Figure 1). The volume of flow is regulated by a valve in the air line and is measured as it flows through a 90° V-notch weir.

A channel has been recently added, permitting sludge to move directly to the aeration tanks by gravity. The return sludge enters the aerator at points where the air diffusers are producing the maximum turbulence. It is immediately and efficiently mixed with the mixed liquor already in the aeration tanks.

The air lift has no moving parts to lubricate or get out of order. It is simple to operate and the cost of supplying the air required is too small to consider. The air meter shows no

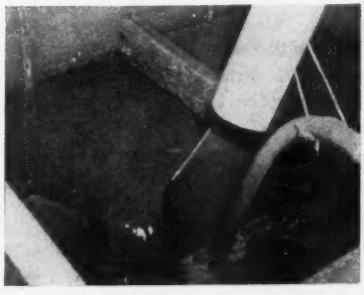

FIGURE 2.—Interior of return sludge measuring box showing 6-in. stove-pipe vent (white), measuring weir, and chlorine feed hose.

readable difference whether the air lift is on or off.

A large vent pipe should be provided for the air lift discharge box to avoid pressure building up inside the covered portion of the box. Such pressure reduces the lifting effect of the air applied below the surface, causing a loss in efficiency. The pressure will also force sludge out through any joints in the cover or through the opening where the air feed pipe passes through the cover. A 2-in. vent pipe was ineffective for the Tenafly installation, but a 6-in. stove-pipe vent proved entirely satisfactory (Figure 2).

Many plants could profitably use one or more of these devices. It is important, however, that they be designed by a competent engineer. Such design is not a hit or miss proposition. Air lifts will work correctly only when they are properly designed and constructed.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Killing time is not murder—it's suicide!
—*Modern Digest*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for extracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Tenth Annual Report of the Belvidere (Ill.) Sewage Treatment Plant for the Year 1946 *

By F. E. Peterson, *Superintendent*

Since weather conditions have an important bearing on the operation of a sewage treatment works, a careful weather record is kept. Observations include temperature, rainfall, and wind direction. A record of the stage of the Kishwaukee River is also maintained. In November 1943, the plant became the official gauging station on the north branch of the Kishwaukee River for the United States Geological Survey.

Operation

The screens are raked five times daily and if necessary, as in case of storms, during the night. The screenings are buried.

The flow meter is checked for accuracy frequently.

Digested sludge is removed from the drying beds by means of a wheelbarrow, and placed in a stock pile. From the stock pile, it is given away to anyone desiring to use it as fertilizer. No trouble has been experienced in disposing of the sludge since it has been stock-piled. However, efforts to have those desiring it to remove it directly from the beds did not meet with success.

All gas drip traps and seals are inspected every day to insure proper operation. The safety devices on the boiler are checked frequently.

Laboratory Control

The operation of the plant is controlled from the information furnished

* Recipient of FSWA 1947 Hatfield Award for plants under 10,000 population.

For previous extracts see: This Journal, **17**, 4, 839; **11**, 5, 897.

by the analytical tests obtained in the laboratory.

The following is a schedule of the laboratory work which was maintained during the year.

Biochemical oxygen demand
Raw, primary, and final
Mondays and Thursdays—one week, Mondays, Wednesdays, and Saturdays the following week.

Suspended solids
Raw, primary, final, and mixed liquor
Mondays and Thursdays—one week, Mondays, Wednesdays, and Saturdays the following week.

Settleable solids
Primary, final, and mixed liquor—daily

Sludge index—calculated daily

Hydrogen ion concentration
Raw, primary, final, and digester—daily

Total and volatile solids
Raw sludge—daily
Digested sludge—as drawn
Supernatant liquor—occasionally
Digester contents—monthly

Methylene blue stability
Final—daily

Dissolved oxygen
Aerators—twice daily
Final effluent—daily
Kishwaukee River (above and below plant)—daily

Oxygen demand of mixed liquor—frequently

The B.O.D. and suspended solids tests are made from composite samples taken hourly in proportion to the flow over a 24-hour period.

Since there is no gas meter, gas production is calculated from the daily additions of volatile solids.

On the last day of each month an analysis is made of the contents of the digester. Samples are taken at 3 ft. intervals and from these samples the per cent dry solids and volatile solids, temperatures, and pH at the various levels are determined.

Records

The data obtained from the analytical tests together with all meter and other readings, such as temperature and stage of the river, are recorded on a daily report sheet. From this sheet the monthly report to the State Sanitary Water Board and other desired information is compiled. In addition to these daily report sheets, a daily log book is kept of important events.

Operating data are summarized in Table I.

TABLE I.—Summary of 1946 Operation Data at Belvidere, Ill.

Item	Average
Rainfall (in.)	21.70
Tributary population	8,100
Equivalent population (B.O.D.)	10,585
Average sewage flow:	
M.g.d.	1.09
Gal. per capita per day	134
Suspended solids:	
Raw (p.p.m.)	198
Settled (p.p.m.)	80
Final (p.p.m.)	3.0
Reduction (%)	98.5
B.O.D.:	
Raw (p.p.m.)	200
Settled (p.p.m.)	96
Final (p.p.m.)	5
Reduction (%)	97.5
Pounds B.O.D. per capita per day	0.182
Aerator operation:	
Average detention (hr.)	7.4
Mixed liquor suspended solids (p.p.m.)	575
Return sludge (per cent flow)	18
Pounds B.O.D. removed per kw.-hr.	0.367
Digester operation:	
Average pH	7.4
Average temperature (° F.)	93
Digested sludge, dry solids (%)	3.57
Digested sludge, volatile solids (%)	54.7
Estimated gas production (cu. ft. per capita per day)	1.61
Operation cost ($):	
Per capita	1.01
Per m.g.	25.50
Pumping station operation cost ($):	
Per capita	0.15
Per m.g.	3.78
Administration cost ($):	
Per capita	0.27
Per m.g.	6.84
Depreciation, interest, etc. cost ($):	
Per capita	1.09
Per m.g.	27.60
Total cost ($):	
Per capita	2.52
Per m.g.	63.72

Annual Operation Report of the Ann Arbor (Mich.) Sewage Treatment Plant for the Year 1946 *

By C. Preston Witcher, *Superintendent*

The year 1945 began with the plant continuing to operate as an activated sludge plant, with consistently good results day after day, and with not a single break in operating efficiency since the activated sludge process was started in September, 1942. This continued process stability was even more significant in view of the fact that recirculation of the digesters has been practiced and large quantities of supernatant have been wasted back to the process each day. This was being done in an effort to speed up the digestion process in order to minimize the lack of digestion capacity.

Contrary to the experiences in most plants, supernatant or digested sludge has been an aid in maintaining a good activated sludge, rather than a hindrance as reported by some plants. In fact, it has been one of the control procedures for several years to add digested sludge or supernatant to the aerators at intervals for the purpose of maintaining a proper balance between the various constituents of the sludge. It is believed that supernatant should be added directly to the aerators since there does not appear to be any benefit to be derived from giving it primary treatment, and there are several disadvantages.

The digesters had not been cleaned during 9 years of operation and it was quite certain they contained considerable grit that might be contributing to the difficulty in maintaining tank temperatures. In emptying the digester pumping was continuous night and day for over a month, with endless backflushing employed in an unsuccessful effort to keep the pumplines from plugging. At the lowest point it was possible to reach, the tank still contained about 14 ft. of material. The heating coils could be seen when down to this point, and since they seemed to be in place and not too badly caked up, it was decided to abandon the attempt to empty the digester and wait until there was more pumping capacity available so that higher velocities could be maintained in the drain lines.

It was decided to abandon the activated sludge process for the winter in order to reduce the liquid loading to the digesters and with hopes of obtaining supernatant and a more concentrated digested sludge which could be handled effectively on the vacuum filter. The change to a straight aeration and settling process did help the digester problem, although breaking into the continuous successful run on activated sludge was regrettable.

Each winter it had been increasingly more difficult to maintain desirable digestion tank temperatures, even though 150° F. water was circulated through the heating coils. It seemed certain that the primary digester must need cleaning and that the possibility of it being full of grit and sand might have some bearing on the heating difficulties experienced. The digester has approximately 500,000 gal. capacity, being 65 ft. in dia. and 29 ft. deep. Everything below 15 ft. must be pumped out of an 8-in. pipe coming from the bottom sump of the digester. When the liquid level was lowered, 13 ft. (average) of sand and grit was found in the tank, with a somewhat less depth at the middle of the tank and the grit piled up higher around the wall. The estimated volume was 1,000 cubic yards.

In dewatering the digester it became increasingly more difficult to keep the sludge line unplugged as the liquid consistency of the tank was reduced. Finally, by jetting with a fire hose

* For last previous extract see: This Journal, **18**, 3, 552.

and nozzle, a 10-in. galvanized iron pipe was sunk to the bottom outlet. By means of this pipe the sand was prevented from sliding into and plugging the outlet.

The top of the pipe was kept trimmed off so as to be about 6 in. below the sand surface, and with fire hoses the grit was sluiced into the tube. In this way the dilution of the grit mixture could be controlled and be kept at a pumpable consistency. At first, all of this work had to be done from ladders and swinging scaffolds, but as the level went down the sand became firm enough to walk on and men were able to start shoveling the material toward the center of the tank.

The heating coils were completely buried in the sand, and as they were uncovered were found to be off the supports and mostly on the floor of the tank. It was possible to jack the coils back onto the supports, with only one break occuring in the process since most of the distortion was taken up in the threaded connections. The job was finally completed after about 8 weeks of hard, disagreeable work.

During the summer the outlet pipes from the aerators into the final tanks were extended so as to give a free discharge above the water line instead of the original subsurface discharge. This was done to improve the distribution of velocities through the final tanks. This change created rather high surface velocities and it was necessary to install floating baffles extending about 12 in. below the surface to dampen these surges successfully.

Plant operation for 1946 is summarized in Table II.

TABLE II.—Summary of 1946 Operation Data, Ann Arbor, Mich.

Item	Average
Total rainfall (in.)	24.54
Connected population	48,200
Equivalent population (B.O.D.)	56,300
Sewage treated (m.g.d.)	5.3
Suspended solids (p.p.m.): *	
Raw	200
Settled	95
Final	23
Per cent reduction	88
B.O.D. (p.p.m.): *	
Raw	216
Settled	166
Final	40
Per cent reduction	81
Activate sludge: *	
Mixed liquor solids (p.p.m.)	1,835
Aeration period (hr.)	5.4
Air used (cu. ft. per gal.)	0.9
Return sludge solids (p.p.m.)	4,890
Amount return sludge (% by vol.)	37
Raw sludge:	
Total solids (%)	3.5
Volatile solids (%)	78.5
Supernatant:	
Total solids (%)	0.84
Volatile solids (%)	64.2
Digested sludge:	
Total solids (%)	1.5
Volatile solids (%)	63.7
Digester gas:	
Cu. ft. per capita per day	1.07
Operation cost ($):	
Per m.g.	24.25
Per capita	0.96
Total cost (including all charges) ($):	
Per mg.	43.25
Per capita	1.72
Amount earned for depreciation ($)	13,383.24

* Straight aeration and double settling to June 10th; activated sludge during remainder of the year.

Sixteenth Annual Operation Report of the DeKalb (Ill.) Sanitary District Sewage Treatment Plant, for the Year 1947 *

By Donald E. Henn, *Manager*

In July, wastes from the canning plant produced a heavy overload on the plant while the canning company was packing one of the largest pea packs in its history in just 31 days. The B.O.D. of the raw sewage was 2 to 3 times that of normal domestic sewage. Very good reductions were ob-

* For last previous extract see: This Journal, **13**, 3, 590 (May, 1941).

tained, but the plant effluent still had the strength and characteristics of settled sewage. Very little dissolved oxygen was available in the plant effluent and the stability was less than 1 day. The river below the plant was watched very closely. Some pollutional type growth was noted in the river for 800 to 1,000 ft. below the outlet. Below this point the river recovered very rapidly.

Weather, especially unusual conditions such as storms, and either wet or dry periods, has a marked effect on the operation of a sewage treatment plant. Many irregularities in operation can be explained only by weather conditions existing at the time. Therefore, a rather complete record of the weather is kept. A record is made of all storms, the condition of the sky each day, the direction of the wind three times a day, the maximum and minimum air temperature, and the amount of precipitation.

Bar Screen

This mechanism, which works under very adverse conditions, is showing some signs of wear and will probably have to be either replaced or entirely overhauled within the next few years.

In January the motor was taken down and serviced. On April 23rd, during a severe storm a stick caught in the bars and bent the arms of the mechanism. The arms were badly rusted and were replaced with new angle iron procured locally.

Secondary Settling Tank

This unit is equipped with a "Dorrco" traction clarifier and provides a 1.25-hr. detention period with a 1.8 m.g.d. rate of flow.

Sludge Pump (Dorrco)

There was no change in the pumping schedule which has now been in force many years. This schedule provides automatic pumping for 15 to 20 min. (depending on time of year) at 1 P.M., 10 P.M., and 3 A.M. by time clock regulation, and manual operation from 20 to 45 min. each at 8 A.M. and 4:30 P.M. The pump is set to deliver 35 gal. per min. to the digester. The above pumping schedule provides for variation in sewage flow and solids to be handled.

Plant Grounds

The year's growing season was started on January 23rd when a few seeds were planted in boxes which were placed in a hot frame at the office. Several thousand plants, consisting of both flowers and vegetables of many varieties, were raised in the hot bed and four cold frames constructed later in the spring. The beds of asters and gladioli which have been an annual feature at the plant, are worthy of mention. Over 1,000 aster plants were raised, of which about 500 were set out at the plant and rest given away. Several hundred blooming-size "glad" bulbs were planted and produced many beautiful blooms. Several hundred small bulbs and bulblets

TABLE III.—Summary of 1947 Operating Data, DeKalb (Ill.) Sanitary District

Item	Average
Total rainfall (in.)	34.09
Tributary population	13,300
Sewage flow (m.g.d.):	
Ave.	1.39
Max.	3.00
Min.	0.63
Suspended solids (p.p.m.):	
Raw	211
Settled	73
Filtered	69
Final	35
Per cent reduction	93.5
B.O.D. (p.p.m.):	
Raw	268
Settled	137
Filtered	39
Final	37
Per cent reduction	84.0
Digester gas produced (1,000 cu. ft. per day)	14.0
Power used (kw.-hr. per day)	80.7
Operating cost ($):	
Total	11,672
Per capita	0.81
Per m.g.	21.40

were planted to produce blooming size bulbs for the 1948 season. Present plans are to plant at least 1,000 "glad" bulbs in 1948. The flower beds not only added greatly to the plant's attractiveness but also furnished flowers for many bouquets given to visitors.

The over 4 acres of lawns were kept mowed and trimmed and the roads to and around the plant were well graded.

Visitors

Several groups of students from the Northern Illinois State Teachers College and one group of high school students visited the plant during the year. Many citizens of the District visited the plant and equestrians continued to use the gravel and cinder road to and around the plant as a bridle path. Every effort was made to keep the plant in a clean and sanitary condition. The grounds and flower gardens attracted many visitors to the plant during the summer months.

Operating data for the plant are summarized in Table III.

USE OF CLOROBEN FOR ODOR CONTROL

By Frank S. Taylor

Filtration Engineer, Oklahoma City (Okla.) Water Department

Oklahoma City has, at present, two plants treating the sewage of this fast growing city of 240,000 population. One plant, the Northside sewage treatment plant, handles about 25 per cent of the flow, which is mostly domestic sewage. The other, the Southside plant, treats 75 per cent of the flow, which is a combined flow of domestic, industrial, and packing-house waste.

The city has spend nearly $1,000,000 for sewage treatment in the past 20 years and has been unable to keep pace with the rapid growth of the city. Primary treatment, augmented with chemical precipitation, is the method of treatment used at the present time.

Sewerage Improvements

The coming of World War II delayed, by about 5 years, the start of extensive improvements to the existing sewerage facilities. A $15,000,000 bond issue was approved in 1946 to provide funds for this work. Of this issue, $5,000,000 was for sanitary sewers, $4,000,000 for two sewage treatment plants, and the balance of $6,000,000 was for storm sewers.

In order to provide some immediate relief to portions of the sewer system supplying the Southside plant, an intensive sewer cleaning program was started. Back pressure had developed in the main sewers because heavy deposits, which resulted from sewer caveins, had reduced main sewer capacities. To facilitate the sewer cleaning work the sewage flow was reduced by bypassing a portion of it directly to the river.

Bypassing Arrangement

This bypassing was accomplished by constructing a sluice gate at the side of one of the main sewer manholes and connecting it to the manhole with a concrete flume. Then the side of the manhole was broken out, and the flow could be controlled. It was necessary to bypass approximately 5 m.g.d. of raw sewage, which contained a large amount of industrial and packing-house wastes, into an abandoned part of an old river channel. The bypassed sewage was discharged at a distance of about a half mile above the junction of the abandoned channel and the river proper.

Bypassing proceeded from August, 1946 to July, 1947 without too much complaint from odor nuisance, although

sludge deposits were observed to be increasing, with active digestion releasing large amounts of gas. The old channel was acting as a settling basin, and digestion was progressively increasing due to the high summer temperatures. Strong hydrogen sulfide odors were released by the sewage as it left the manhole sluice gate discharging into the channel.

Cloroben Selected for Odor Control

Having read of the experience of Reuben F. Brown in the use of Cloroben for up-sewer treatment at Los Angeles (1), it was decided that this new chemical had possibilities for use in reducing the hydrogen sulfide odor in the bypassed raw sewage and for clearing the odors from sewage and sludge deposits in the abandoned river channel. The Cloroben Company was contacted and their field engineer investigated the situation. It was decided that Cloroben could be of help in controlling the odors, and permission to purchase and apply some was given by M. B. Cunningham, superintendent-engineer of the Water Department, who, incidentally, had also heard of its use in Los Angeles while attending the joint AWWA and FSWA conference at San Francisco in July, 1947.

Cloroben, a chlorinated hydrocarbon, is an amber color liquid of pleasant odor, which forms a milky emulsion when mixed with water. The emulsion will remain suspended for several days even in a solution as dilute as 2 per cent. It is entirely stable, does not liberate chlorine or produce phenols. It is noncorrosive, noninflammable, and safe to use. The workmen handling the liquid can do so with perfect safety.

Dosing Equipment and Schedules

A 250-gal. steel tank was placed on the 24-in. main sewer at Rotary Park, Station B, about 4 miles upstream from the bypass point. The packing-house wastes are tributary to this sewer. Twenty-five gallons of Cloroben were added to 225 gallons of water, making a 10 per cent solution. This was added as a shock dose and was applied to the sewage flow over a period of 24 hours. The flow averages approximately 4 m.g.d., 50 per cent of which is packing-house wastes. The Cloroben feed was regulated by a ¾-in. gate valve (Figure 1). No stirring device was needed to keep the Cloroben in suspension, as the emulsion formed readily.

FIGURE 1.—Storage tank and feed regulating valve used at Rotary Park, dosing station B.

A second dosing station, Station A, was installed at the 24-in. sewer leaving the Wilson Packing Company approximately 6 miles above the bypass point and 2 miles upstream from Station B at Rotary Park. Two 55-gal. steel drums were joined with piping to give a 110-gal. container. A regulating valve was used for dosing over a 24-hour period (Figure 2). It was believed that these two stations would provide the desired pretreatment of

the sewage before it reached the bypass point.

A third dosing station, Station C, was installed on a 15-in. sewer, which in turn empties into the 24-in. sewer carrying domestic sewage to the bypassing point. Cloroben was applied by using a 55-gal. steel drum with regulating valve.

The amounts of Cloroben applied at the three dosing stations are given in Table I. All treatment was stopped Oct. 17, 1948.

On August 12, 1947 the river channel at the bypass was given a shock treatment of Cloroben for a period of 3 hours. A dosage of 10 gal. per hour was used. By use of a portable pressure pump the Cloroben was applied through four spray nozzles which discharged under the surface of the sewage at a pressure of 120 lb. per sq. inch.

Results of Cloroben Treatment

A decided improvement in the odor of the raw sewage being bypassed followed the first application of Cloroben at Station B on August 11, 1947.

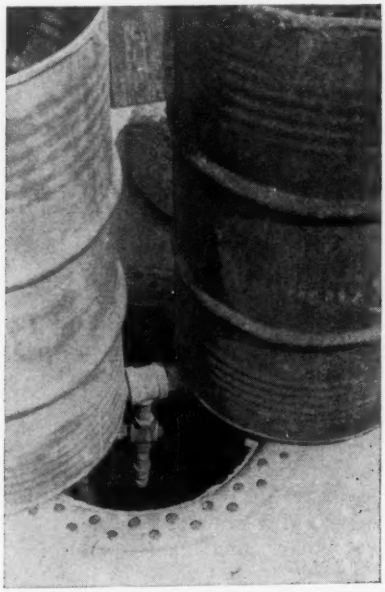

FIGURE 2.—Two 50-gal. steel drums used at dosing station A on Wilson Packing Company sewer.

TABLE I.—Rates of Application of Cloroben

Date	Application Point	Amount of Cloroben Added
Aug. 11, 1947	Sta. B	25 gal.
Aug. 12, 1947	Sta. A	10 gal.
	Sta. B	15 gal.
Aug. 13, 1947	Sta. A	5 gal.
	Sta. B	10 gal.
Aug. 14, 1947	Sta. A	3 g.p.d.
	Sta. B	10 g.p.d.
	Sta. C	2 g.p.d.
Aug. 20 to Oct. 17, 1947	Sta. A	3 g.p.d.
	Sta. B	6 g.p.d.
	Sta. C	2 g.p.d.
Oct. 18 to Dec. 14, 1947	Sta. B	6 g.p.d.

On August 13th, the floating patches of solids and greases that had previously covered the channel had been dissolved for a considerable distance down stream. The color of the sewage was begining to change from black to brown, and the odor was noticeably reduced. By August 20th, conditions had improved to such an extent that the Cloroben dosage at Station B was cut to 6 gal. per day and continued on that basis until October 17th.

Bypassing of raw sewage to the abandoned channel was discontinued Oct. 6, 1947.

From the results obtained it is believed that the use of Cloroben was very successful in preventing an odor nuisance during the bypassing of a strong raw sewage into the abandoned river channel, particularly during the severely hot weather. Odors were reduced to where they were hardly noticeable; hydrogen sulfide was practically eliminated.

Cloroben was purchased at a cost of $2.25 per gal., in 55-gal. steel drums.

The so-called "shock" doses require a treatment of about 10 p.p.m. by vol-

ume—that is, 10 gal. per m.g. of sewage treated—and routine doses consisted of about 2 p.p.m., or 2 gal. per m.g. of sewage treated. These amounts were sufficient to prevent hydrogen sulfide formation.

Other Uses for Cloroben

Some experimenting was also done with the use of a 2 per cent solution as a spray for storm sewer catch basin traps. The storm sewer traps become very odorous during the hot summer days when no rainfall occurs, and the public offers a justified complaint. It was observed that spraying would keep odors down perfectly for 2 to 3 weeks. Routine spraying now has been adopted as a routine procedure during the dry, summer months. Another idea that came to mind was to follow the regular street flushing by final spray with a 2 per cent Cloroben solution. This final spray would then drain into the catch basins and remain in the traps to hold down septic odors. It was not necessary to use this treatment, however, as the direct spraying of basins proved effective.

A 2 per cent solution was also used to good effect at both sewage treatment plants for control of odors from the bar screenings and the platforms around the screens.

One of the water department customers, a Help-Yourself Laundry where facilities are provided for the customer to wash family clothes, asked for advice about something to reduce odors in sewer traps serving the laundry machines. Cloroben was recommended and it did the job.

Summary

Summing it all up, experience at Oklahoma City has indicated that Cloroben is a good chemical to have available for emergency odor control treatment of sewage and for general odor elimination work.

SEWER MAINTENANCE AT WICHITA*

By George J. Fisher

Superintendent of Sewers, Wichita, Kansas

The city of Wichita, Kansas, with a population of about 170,000, has a sewer system composed of 363 miles of sanitary sewers and 93 miles of storm sewers. Most of the system is rather old, and the grades are flat. Some of the trunk sewer lines are so overloaded that flow from the laterals is greatly retarded, thus creating undesirable septic conditions in the system.

One lateral flows uphill because of the load on the downstream end of it. So much sewage goes into this 8-in. line from a creamery and other plants tributary to it that the sewage backs up and flows into the manhole at the upstream end.

However, most of the sanitary sewer system is working quite satisfactorily. This is also true of the storm system, except, of course, during heavy rains which overload it as they occasionally do any storm water system.

Sewer Maintenance Crews

To maintain these 456 miles of sewer lines and appurtanences a crew of 19 men are employed consisting of:

One general foreman
One emergency crew of three men
One general repair crew of two men
One sewer drag crew of three men
One flushing crew of two men
One pump maintenance crew of two men
Two general duty crews of two men each
Two sewer inspectors

* Presented at the Third Annual Meeting of the Kansas Sewage Works Assn., Wichita, Kansas, March 11–12, 1948.

The two pump maintenance men take care of the three sewage pumping stations which are required to pump the sewage from the portion of the city lying west of the Arkansas River to the east side of the river.

The sewer maintenance crews are equipped with:

Three dump trucks
One emergency truck, especially designed for this work
Three pickup trucks
One flusher truck
Two passenger cars
One sewer drag machine
One 4-in. and one 2-in. pump
One lighting unit
Miscellaneous other tools and small equipment.

In 1947 the following work was accomplished with a budget of $47,306. The 1948 budget is $52,412, or $115 per mile.

Sewer connections inspected	2,200	
Catch basins cleaned	26,435	
Manholes and sumps cleaned	405	
Sanitary stoppages opened	524	
Storm stoppages opened	976	
Sanitary sewers dragged	2,924	ft.
Storm sewers dragged	13,096	ft.
Sanitary sewers flushed	5,612	ft.
Storm sewers flushed	33	ft.
Catch basins reconstructed	75	
Manholes reconstructed	120	
Sanitary sewers repaired	48	
Storm sewers repaired	12	
Trouble calls answered	130	

Sanitary Sewers

On the sanitary sewer system the manholes are spaced a maximum of 300 ft. apart, and no new ones are installed at a greater distance. This maximum distance was adopted to facilitate maintenance and the opening of stoppages.

Stoppages are opened by using a flexible steel rod unit, with augers for cutting roots. After the stoppage is opened the sewer is dragged, if necessary, to prevent future trouble with sand and other debris. Flushing also is resorted to when necessary. Manholes are cleaned as required.

In 1948 the use of Cloroben was begun to dissolve grease and soap in the sanitary sewers, especially in the downtown sewers and in the sewers that service the stock yards, meat packing plants, and other such industries in the northern part of the city. This chemical is sometimes used in the flusher truck with some success. If the use of this chemical continues to be successful, it is probable that a continuous drip system of sewer application will be adopted.

The emergency crew receives about 100 calls per month, approximately one-third of which result in finding actual stoppages in the city laterals. The other calls generally result in finding that a private sewer is stopped up or that something else besides a stoppage is wrong.

In normal times the sanitary sewers are flushed regularly, the flusher following established routes.

Many items of general maintenance are also taken care of as time permits, such as:

Rebuilding manholes and adjusting them to grade,
Raising sunken sections of sewers,
Making tops to sewer laterals for plumbers.

A tendency toward the adoption of garbage grinders is apparent in the city, and the use of this household convenience is permitted. There are not enough in use yet to produce any apparent changes in sewage flow. Several inquiries have been made to the city by industries concerning the grinding of garbage, but as yet no industry or business has adopted the method so far as is known.

Storm Sewers

The storm water sewer system is maintained similarly to the sanitary

system. Stoppages are opened with a flexible steel rod unit and the sewer is flushed and dragged as necessary.

On this system the catch basins, inlets, and sumps require regular cleaning, and the two general duty crews are kept quite busy on this work. During heavy rains all sewer maintenance personnel except the sewer inspectors are assigned routes for opening stoppages, cleaning catch basins, and other work necessary to eliminate flooded conditions on the streets.

Wichita has many siphons across its intersections. These are a constant source of trouble because they clog easily and because the stagnant water in them creates objectionable odors in hot weather. An attempt will be made to eliminate the latter trouble with injections of Cloroben this summer.

As noted in the table of work accomplished in 1947, many manholes, catch basins, and inlets have to be repaired annually. Passenger cars, trucks, buses, and playful children damage many of them, resulting in the necessity for the repairs.

Sewer Taps

The Sewer Division of Wichita inspects all taps made into the laterals and mains of the sanitary and storm sewers. Wyes are placed and accurately located when the laterals of the sanitary system are built. Connections to the sanitary system must be made at these wyes. Usually they can be found, but occasionally they cannot because of errors of measurement. The licensed plumber is required to dig at least 3 ft. in each direction of the wye location given him at the city building. If the wye is not located in this distance, the city taps the line for him free of charge. When an existing wye cannot be used, the city taps the line at the expense of the plumber. No one but the city sewer maintenance crews are permitted to tap city sewer lines for connections.

The city sewer inspectors check the house sewer from a point 4 ft. from the residence or building to the city sewer. They see to it that the alignment and grade are proper, that the bends are not too sharp, and that a proper connection is made to the city sewer.

Air Conditioning Problems

One of the greatest problems of water disposal in Wichita is in connection with air conditioning units. A city ordinance forbids connecting such units to the sanitary sewers because of the overloaded condition of some, and because such unrestricted connections to the sanitary system would soon overload those sections which now carry their load satisfactorily.

Users of air conditioning equipment must either discharge the used water into a storm sewer, use an evaporative condenser, dig a well, or erect cooling towers. If none of these methods is practical or economical, the prospective user is just about out of luck. Perhaps the manufacturers of air conditioning units should conduct some research concerning the possibility of a practical and economical self-contained unit of capacities from 5 to 10 tons, so that smaller businesses which cannot connect to storm sewers or dig an effective well, and which cannot afford expensive condensers or cooling towers, may still air condition their establishments.

All in all Wichita has its routine, difficult and peculiar sewer maintenance problems much like any other city. Its maintenance crews have a large job on their hands, and that job will not get any smaller because Wichita is expanding and growing in population every year. Many predict that its population will be 250,000 or 300,000 by 1955. If that happens there will be many more miles of sewers to maintain, a greater complexity of problems, and, it is hoped, a larger maintenance force to take care of them.

COMMERCIAL UTILIZATION OF WASTE DIGESTER GAS

By John J. Wirts

Asst. Construction Engineer, Dept. of Utilities, Cleveland, Ohio

In these days of shortages of gas for domestic and industrial uses, the "eternal flame" often seen from the outside of a sewage treatment works should be considered from the public relations point of view. Most sewage works men on more than one occasion have been asked, "Why not put the excess digester gas into the local gas utility system?" It is natural for the layman to question the efficiency of the sewage treatment process when an obvious waste of heat can be seen even during the winter months.

Perhaps many sewage works men themselves have questioned the waste inherent in burning excess digester gas and have wondered about the practicability of supplying waste gas to the local gas utility. On the surface, such action has an element of common sense, provided, of course, the mechanics of effecting connection with the local gas system are within the limits of practicability.

The matter of utilizing the waste gas from sludge digestion by feeding the gas into a local distribution system, however, has many ramifications. Requiring evaluation are many important considerations other than the amount of waste gas available and the feasibility of making the required connection between the sewage plant and the gas system.

Heat Content

One of the factors to be considered is the heat content of the gas. Nearly all gas utility companies are obligated by their contractual or franchise agreements with municipalities in which they operate to deliver gas having a heat value of more than 950 B.t.u. per cubic foot. For this reason any gas purchased must have at least that heat value content. Since waste digester gas does not average more than 650 B.t.u. heat content, enrichment or concentration of the gas before discharge to the utility system would be required.

The work and equipment involved in adequately controlling the heat content of digester gas would be considerable. Fluctuation of the B.t.u. value of the gas with variations in sewage flow and composition, plant loading, and methods of plant operation may be expected and would require some type of control. The frequent testing necessary for adequately ascertaining sewage gas heat values alone would burden the average sewage works laboratory staff. Operation and maintenance of control equipment would make further demands on the time and ability of the sewage works personnel.

Variable Sewage Gas Characteristics

Other sewage gas characteristics than the heat content also vary widely with changes in sewage composition and plant operation methods. Several of these changing characteristics, such as specific gravity, moisture content, etc., might cause trouble due to the sensitivity of much of the gas appliance control equipment used today. It is not practical to introduce into a natural gas system other gases that differ materially from natural gas.

Before sewage gas could be made acceptable for a natural gas system the carbon dioxide would require removal in order to prevent a lowering—in effect a dilution—of the heat value of the natural gas receiving the sewage gas. This would be a significant item in the conditioning requirements since the carbon dioxide content of sewage

gas will average as much as 20 to 30 per cent by volume. A considerable amount of the carbon dioxide would undoubtedly be removed by whatever process was employed in adjusting the heat content of the sewage gas to that of the natural gas.

Hydrogen Sulfide

A continuous check on the hydrogen sulfide content of sewage gas also would be required because of the corrosive properties of hydrogen sulfide in moist atmospheres. Removal would be necessary if the concentration exceeded 0.07 per cent by volume, or about 50 grains per 100 cubic feet. Such removal would not be prohibitive from a cost standpoint, but careful control of the process would necessitate considerable work.

Gas Pressure

The pressures carried in utility gas mains are considerably greater than those in the gas collection systems of sewage works. Compressing, and perhaps storage, equipment would be necessary for a sewage gas hook-up with the natural gas system. Thus, plant investment and operation and maintenance work would be increased.

Franchise Limitations

The service contracts or franchises of many gas utilities require that the gas utility distribute only natural gas. These contracts do not permit the introduction of manufactured gas, into which category the waste gas from sludge digestion would fall. Consequently, in many places before waste gas could be used by the utility, it would be necessary to alter contracts or franchises with all the municipalities served. The difficulties involved are apparent.

Summary

Investigation into the cost of meeting the conditioning and purification requirements for augmenting the gas utility supply with waste digester gas has disclosed that there would be little or no gain in the venture under present economic conditions. The present cost of natural gas and its relatively plentiful supply make competition with or supplementation of the utility supply unprofitable. In the study from which these conclusions were drawn the quantity of gas wasted during a year was 124 million cu. ft., with a maximum month of 16 million cu. ft., and a minimum month of 3.6 million cubic feet.

The most simple and profitable solution of the waste gas problem is to burn these gases in the nearest boiler installation, provided conveyance of the gas to such installation is physically and economically feasible. The regular fuel supply requirements would be decreased by the amount of waste gas available. By the installation of storage equipment continuity of supply could be assured during periods when the regular fuel source was in short supply. This solution assumes that maximum use is made of digester gas at the sewage treatment works and that there usually will be a variable supply of waste gas.

TIPS AND QUIPS

Complete Your Journal File

Many Federation members have inquired about the possibilities of obtaining the back issues missing from their JOURNAL files. There must be many more who have wondered about this, but who have never taken time to inquire about it.

During the war years many members failed to receive one or more copies

of the JOURNAL. This was inevitable in view of the large number of people moving about and the subsequent flood of temporary and forwarding addresses. Many JOURNALS were not forwarded by those who accepted delivery, and in countless cases forwarding instructions were not available for the JOURNALS returned because of changes of addresses or other reasons.

Frequently inquiries about the availability of the earlier issues of the JOURNAL are also received. The reference value of JOURNAL papers is universally recognized, and complete files of the JOURNAL are greatly prized by their owners. For the newer members of the sewage works field, copies of back issues provide the background information and understanding needed for meeting present day problems. Many JOURNAL papers are classics of their kind and are as authoritative now as when published. The bibliographies of many of these papers are also of reference value.

Fortunately, your Federation headquarters is able to supply nearly all of the back issues of the JOURNAL. Copies of the original printing of many issues are still in stock. Copies of those which are out of print have been obtained by purchase and donation from members and friends. Occasionally the estate of a deceased member will yield several scarce out-of-print issues. By these means, such back issues continually become available.

A card or letter to the headquarters office will bring a prompt mailing of the back numbers desired. The cost of $1 per copy is nominal, only a few cents more than the original cost. If the issue desired is not available, the request will be held and filled at the first opportunity.

Why not complete your JOURNAL file now? That missing issue may contain the information you'll need tomorrow!

New Light on an Old Subject

A novel way of providing the necessary light in a sewer for a good inspection job is reported by Walter H. Brown, Jr., Cranston, N. J., sewage works operator. For sometime mirrors have been used very successfully for this purpose at Cranston.

In its application, the idea is simplicity itself. One man stands at the top of the manhole and reflects the sun's rays to the bottom of the manhole where another mirror is held so as to catch the light and reflect it through the sewer.

On sunny days the amount of light a mirror can reflect into a sewer is surprisingly large, and quite sufficient to be seen several hundred feet downsewer, if the sewer is open. Far more light can be concentrated in the sewer in this way than can be obtained by using a portable light.

The secret, of course, is to use fairly large mirrors. An unhappy experience with the 6-in. Cranston mirrors aptly illustrates their light gathering and concentrating capacity. One noon hour a mirror was left lying face up in the rear of a covered utility truck near the tail gate. In short order the truck's top lining was burned out. The Cranston mirrors must have been concave mirrors to have effected such a concentration of sunlight at one spot.

A special carrying case now prevents future fires and protects the mirrors when not in use.

Sludge Shower Shocks Satterthwaite

A November open-air shower in Indiana is apt to shock anyone, particularly the individual being showered. The effect on Philip Satterthwaite, truck driver of the Marion (Ind.) sewage plant, can easily be imagined, especially since Satterthwaite was adding a new twist—that of using sludge instead of water!

It all happened, carelessly enough, when Satterthwaite started to fill the

liquid sludge tank truck with the sludge inlet pipe turned up into the air instead of into the tank. The reaction was prompt; the wetting thorough; the lesson well learned. This probably will not happen again soon, at least not to Satterthwaite.

A Reminder About Christmas

It's a little early to order the Christmas turkey, but here is an idea that may start your thoughts along that line. Each Christmas the employees of the Marion, Ind., sewage treatment works enjoy a grand turkey dinner at the plant with their superintendent, David M. Backmeyer. It's an annual affair now, and as much a part of Christmas as Santa Claus.

Somehow, this custom has the touch of genius about it. Is there any better way of erasing the irritations and easing the tensions of the old year? Or of figuratively joining hands for the team work of the new year? Or is there a better season to do both?

The way to a man's heart is no mystery—and the Christmas season is no exception!

Something Easily Remembered

Back in the early days when the fathers of science were carefully nursing the seedlings of physical knowledge, it's a shame they didn't do something about temperature. It's not the heat that causes trouble, or the lack of it. It's just the difficulty involved in trying to remember how to substitute one yardstick for the other when measuring the stuff. "Let's see: Fahrenheit equals Centigrade plus 32 times 9/5, or is it minus 32 times 5/9, or could it be times 9/5 minus 32? Ah—where's that handbook?" See?

One of the best things heard at the Central States meeting in Milwaukee last June was a sure-fire way of remembering how to convert Centigrade to Fahrenheit. This handy tool was picked up over the dinner table and is attributed to the fertile brain of James Brower, superintendent of the Milwaukee sewage treatment works.

Brower's method is simple and easily remembered. Best of all there are no awkward combinations of figures or tricky arithmetical operations to slow up mental calculations. Here it is:

Degrees Centigrade times two, minus 10 per cent, plus thirty-two equals degrees Fahrenheit.

For the mathematical minded, the formula form is this:

$$(°C. \times 2) - 10\% + 32 = °F.$$

Try it on a few awkward conversions and see how easy the mental manipulations are. But don't throw away that handbook until someone thinks out as easy a way to reverse the process.

Selling Safety

One of the best safety promotions seen in months is the little booklet entitled "Safety," which was recently distributed to the entire personnel of the Allegheny Ludlum Steel Corp. of Pittsburgh, Pa. Covering all phases of safety in simple but direct style, this booklet presents the value of safety in convincing fashion. The illustrations are particularly effective.

One of the many cleverly phrased safety suggestions the booklet features is this one: "Don't bring liquor into the plant—externally *or* internally!" And on the last page it leaves with the reader this pointed message:

"Safety is simply a matter of using your head to save your skin. And it's a matter of helping one another. If you're an experienced hand, look after the new man. If you see a friend working carelessly, tell him how to work safely. Set a good example."

A few of these booklets distributed among your sewage works personnel could not but help revive the safety mindedness of all employees.

Antidote for Filter Ponding

An ingenious method for reducing minor ponding of trickling filters by manually reversing the direction of rotation of the rotary distributor arms was reported in a recent issue of *The Clarifier*.

Charles Berry, in charge of the sewage treatment plant at the Rapid City (S. D.) Army Air Base, has found that by moving the distributor backwards very slowly, the liquid coming from the orifices appears to dislodge the filter growth on that side of the rock which is protected from the direct force of the sewage during normal rotation.

This is an excellent example of how an intelligent operator can prevent the development of a serious operation difficulty by using ingenuity and common sense in dealing with a minor problem. Sewage plants are not exceptions to the rule that when minor problems are properly handled, there are no big problems.

Spotting Potential Sewer Trouble

At the Central Section Meeting of the Illinois sewage works operators, Carl Fuss, superintendent of water and sewerage, Mattoon, Ill., described an interesting and practical method of examining sewers for crown and side cracks and for root accumulations. It consists of floating a light down the sewer and watching its progress with a mirror.

Before the manhole is entered, the covers are removed from at least three, and preferably four, manholes above and below the one entered. Sufficient time is allowed for the thorough ventilation of the sewer. A lantern or electric torch is placed on a stable float, a stout line attached, and the float started down the sewer. Sufficient depth of water to carry the float can be obtained at low flows by installing a temporary weir or stop plank in the down-sewer manhole.

Progress of the light down the sewer is watched in a mirror. By carefully regulating the rate of travel of the float, a very good view of the sewer interior can be obtained. Root growths of any size are readily seen and crown and side cracks which might lead to sewer collapse can be easily spotted.

Locating these potential troublemakers permits scheduling and effecting remedial work before complete stoppage or actual sewer failure occurs. Experience with a sewer system generally will indicate the locations where regular or occasional inspection is required.

First Aid for Discolored Paint

The results of using lead-base paints at sewage works are well known to experienced sewage works men, most of whom have learned the hard way. Less experienced men are learning too, but generally find it impossible at once to repaint a job that has started to discolor.

The following tip from "Paint Power," an easy-to-read informative volume published by the paint industry, may prove useful in lightening the discolored areas and thus improve their appearance.

"Hydrogen sulfide fumes from sewage, industrial plants, and other sources tend to darken some paints to a metallic gray resembling graphite. By sponging the surface with hydrogen peroxide or other bleaches—or a dilute solution of muriatic acid—the discoloration may be made to quickly disappear."

As an effort to make the best of a bad situation, the above is of value. There is no substitute, however, for a knowledge of paints and for thoroughly checking paint specifications.

A Family Affair

Although not the oldest sewage treatment works in this country, the

Marlborough plant is one of the oldest —the seventh oldest, to be exact, if U.S.P.H.S. statistics are correct. Built in 1891 and modernized in 1929, the Marlborough plant has served its community for more than half a century.

Its chief distinction, however, is not its age but the fact that for all these years plant supervision has been the responsibility of one family. For three generations the Hansens of Marlborough have been operating the sewage treatment works!

The first plant operator was Chris Hansen, who supervised the plant for many years and was succeeded by his son, John Hansen, the present chief operator. Assisting John now is his nephew, John Hartley, grandson of Chris Hansen, who some day, in turn, will be chief operator.

Such a succession of public servants is rarely encountered in these days of quick dissatisfactions and hasty decisions. There have been several father and son combinations in our field, but does anyone know of another father, son, and grandson succession such as that of the Hansen family at Marlborough? If so, let someone make the fact known so that *The Corner* may wish them, as it wishes the Hansens and John Hartley of Marlborough, many more years of family service.

Tips on Care of Pressure Gauges

Although pressure gauges are not items of sewage treatment works equipment used in quantity, many plants do have several of such gauges to service and maintain. Frequently a casual inspection is sufficient to indicate the lack of understanding with which such gauges have been serviced.

Since gauge repair or replacement is an expensive proposition and one entailing considerable delay, the following suggestions on the care of pressure gauges by J. V. Tracy, Sales Manager, Certified Gauge and Instrument Company, as contained in a recent issue of The J. W. Murphy Company's *Metering Messages*, should be worth while placing in the "File for Frequent Reference" drawer.

Pressure gauges are instruments. They should be handled with as much care as a clock. Don't treat them like a piece of ordinary plumbing.

Selection

It is common practice to specify the dial graduation of a gauge at about double the working pressure. Select the standard range nearest to twice the working pressure. This will make the gauge last longer, and the pointer will be in a more readable position.

Use gauges of the proper tube material for the service. Get the right gauge for the job.

Use a good grade of plastic dials, which are easy to read, easy to clean, and rust and corrosion proof.

Installation

Don't screw the gauge into piping by using the gauge case as a wrench. Use a pipe wrench on the wrench flats which are provided on the gauge socket. When a fitting is being screwed onto the gauge, hold a wrench on the socket flats, instead of twisting against the gauge socket screws which are intended to hold the gauge mechanism in the case.

When the gauges are wall or panel mounted, make sure they are connected up free from piping strains. Check to see that mounting surface is flat or use washers under case flanges to obtain three-point suspension. Preferably, the last length of piping leading up to the gauge should be flexible tubing. This will insure that the gauge is free from strain.

If possible, mount gauges where they will be free from the effects of mechanical vibration. If a gauge is on a badly vibrating machine, try to mount the gauge on a wall nearby and connect by flexible tubing. Also mount gauges where they will be free from moisture and corrosive fumes, if possible. Ordinary cases are not intended for severe conditions. Where these are unavoidable, ask for special recommendations, and in general, use plastic cases, which are resistant to most corrosive fumes and cannot rust.

Don't locate gauges where they will be subjected to high temperatures. Undue heat weakens the tube joints. Also, high temperatures make gauges inaccurate. Always use a siphon for steam applications, and make sure it is filled with water before installation.

When the system is subject to occasional vacuum, provide a leg of piping which cannot be emptied by the vacuum effect. A drain cock or plug should be installed at the bottom of this leg, to enable occasional cleaning out of the sediment. The head effect of this piping leg should be compensated for by resetting the pointer. This is easily done by means of the Hairline Pointer Adjuster which is standard on all Certified gauges.

Protect the gauges from rapid pressure fluctuations by using dampening means such as throttle screws, or needle valves, which can be adjusted to the exact orifice required.

Proper Use

Apply pressure slowly. Don't open the gauge cock or valve too quickly—this imparts a severe strain on the Bourdon tube which may rupture it, or result in shortened life. When the service itself is subject to sudden pressure applications, use a needle valve, or a snubber.

Sudden pressure release has the same detrimental effect, and should be compensated for in the same manner.

Avoid overpressure. See that apparatus is provided with a relief valve, and that the gauge range is higher than the set pressure of the valve.

Maintenance

Replace broken glasses and thus keep dirt out of the bearings. Never oil gauge movements or linkages. Oil attracts dirt, and becomes gummy, thus causing the gauge to be sluggish and inaccurate.

An Item to Remember!

Do you remember when:

People went to Detroit to pick up new cars—and thereby saved the transportation cost?

Father Coughlin, whose church was just two coils and a kilocycle from Detroit, was radio's loudest drawing card?

Belle Isle, Detroit's gentile Coney Island, was the only place a midwesterner could find red bananas?

Ty Cobb, not Walter Reuther, was the idol of Detroit's working man?

Detroit hotel rooms were a dime a dozen, and a "confirmed reservation" was as unknown as a "60-day delay" in Ford deliveries?

Well, if you can, just forget them, because they're all of the past! Especially the last one!

But don't forget to make your hotel reservation for the Twenty-First Annual Meeting at Detroit next month, Oct. 18–21st. The convention hotel, the Statler, has reserved a large block of rooms for Federation members. Rooms have also been set aside at the Book-Cadillac Hotel, which is just a short walk from the Statler.

Write directly to these hotels for your reservation and be sure to mention the Federation meeting. If rooms are no longer available at the hotel you contact, your request will be referred to the Convention Bureau and a reservation made for you at another of Detroit's fine hotels. Everyone will be taken care of if arrangements are made in advance.

Write now for your reservation and avoid that room-clerk glare!

Editorials

THE BACK DOOR TO THE RIVER

It was just a typical grass-roots operators' discussion of sludge digestion headaches until a prominent plant superintendent—one of the best in the land—referred to his "black market" pipe, used for draining sludge to the river when emergencies arose. One or two similar admissions followed, with references to practice at the Atlanta Clayton plant and to the proposed plant at Portland, Ore., where digested sludge will be bled into the primary tank effluent as it flows to the Columbia River. The casual listener would have concluded that only the most naive operator troubled himself about sludge treatment and disposal, if the sludge was digested, of course!

Fortunately, the above discussion soon encountered some strong countering argument. I, for one, can see no justification for the discharge of sewage solids, digested or not, to a stream after they have once been removed from the sewage flow. Certainly it is inconsistent where outlet stream usage and limitations have required the installation of complete treatment works. Even in the case of partial treatment plants, it is drawing a fine line to presume that the objectionable aspects of raw sewage pollution are satisfactorily controlled by the destruction of 75 per cent of the volatile matter in the settleable solids. The cost of treatment per unit of B.O.D. or solids removal would certainly be quite high.

The "Portland Plan" is based on experience at the Los Angeles County Sanitation Districts plant, where digested sludge has been discharged to the Pacific Ocean. Its proponents defend it by emphasis on the fact that the Columbia River at Portland has a minimum discharge of 75,000 c.f.s. This situation is therefore a highly specialized one, and it is not an acceptable citation in support of sludge disposal by dilution for other inland cities. Even for Portland, the plan is proposed only on a trial basis for the early years of operation.

World War II has been blamed for many current dilemmas, and it is probably the culprit in this case. Doubtful practices might have been condoned when labor was scarce, materials were hard to find and new construction was out of the question. "Emergencies" were frequent under those circumstances. Resort to questionable remedial measures was by necessity rather than by choice, and standards of performance suffered thereby.

What else is one to do when his digesters, storage tanks, lagoons and drying beds are filled to the brim? This can not happen so suddenly that an alert operator is unable to warn his Council or Board that added permanent capacity is required. New construction is costly now, but badly needed facilities should not be deferred on that account alone. In the meantime, a spacious lawn is better used as an emergency lagoon, vacuum filters are worked three shifts, sludge is removed from drying beds as soon as it can handled, or wet sludge is hauled away in tank trucks for disposal on land. No operator can be expected to resort to a "sneak valve" to postpone improvements that are required in order for a plant to perform its intended purpose. There is always some other "out" than that back door to the river!

To be sure, the legitimate emergency measures are usually more bothersome and expensive. They have a substantial nuisance value, however, in that the need for adequate capacity expansion can not be overlooked or forgotten. Permanent corrective action will receive administrative support when the exigency is apparent.

Suitable sewage by-pass facilities have a proper place in a sewage treatment plant. They serve to protect treatment processes, equipment and structures from damaging overloads under extreme conditions, and to facilitate necessary maintenance and repair. But sludge quantities are relatively small in proportion to sewage flow, and its by-pass to the plant outlet is always avoidable in some fashion.

There is no need for that back door to the river! W. H. W.

FSWA CONVENTION—1948 MODEL

Elsewhere in this issue will be found a complete outline of the Federation's Twenty-First Annual Meeting at Detroit on October 18–21. It is portrayed as an event that no one should miss—and properly so. To establish the proper atmosphere, however, we should preview the occasion in language that is typical of the Automobile City—

Only the *FSWA Convention–48* offers the up-to-the-minute *Sewage-flo Program* with *Industriflex Forum!* Relax in the *Cloud-Ride Chairs* of the Statler's Grand Ballroom and take in those *Informotomic Papers* as they are delivered by *Tip-Topicked Authorities*—under *Split-Precision Presiding.*

The *Duo-Stop Inspection Trip* and *Picture-Window Manufacturers' Exhibit* will both feature the improved *Audi-View Service.* You get to hear all about it while you look!

Entertainment? The exclusive FSWA *Joyomatic* (*Non-Bore*) *Design* will please the entire family. The lady traveller will particularly appreciate the *Femi-Rite Special Events* and *Barg-n-Pact Shopping.*

Cordioramic Hospitality—standard equipment in all FSWA Member Associations—will be demonstrated at its best by our Michigan hosts. *Climatized Weather* is available to all registrants at no extra cost.

The conventional *Ezypay Registration Plan* (lump sum; one bite and its over with) will prevail.

THERE'S AN FSWA CONVENTION–48 IN YOUR FUTURE . . . AT DETROIT ON OCTOBER 18–21!

W. H. W.

Proceedings of Member Associations

ARIZONA SEWAGE & WATER WORKS ASSOCIATION

Spring Conference

Globe, Arizona, April 2–4, 1948

The 1948 Spring Conference of the Arizona Sewage and Water Works Association, held at Globe, Arizona, April 2–4, was attended by 115 members and guests.

Mayor Guy V. Morgan, of Globe, welcomed the members of the conference and opened the first technical session with a report on the history and development of the Globe, Ariz., water supply. Other opening session papers were:

"Cathodic Protection," by Frank MacDonald, Electro Rust-Proofing Corp., Chicago, Ill.

"History, Development, and Manufacture of Welded Steel Pipe," by Vic H. Householder, Armco Drainage and Metal Products, Phoenix, Ariz.

"Small Activated Sludge Treatment Plants," by Miles Lamb, Chicago Pump Company, Chicago, Ill.

The afternoon session featured a paper by John Girand, Johannessen and Girand, consulting engineers, Phoenix, Ariz., having the strange title "An Assumption Times an Assumption Divided by an Assumption Equals a Fact." The "Operators Roundup," conducted by Reamy C. Fitch, Arizona State Health Department, attracted unusual attention and interest. The technical sessions for the first day were closed by a general discussion of the papers presented during the day. John A. Carollo, of Headman, Ferguson, and Carollo, consulting engineers, Phoenix, directed the discussion.

The Friday evening dinner for the members and their ladies featured an address by Dr. Robert Nugent, vice president of the University of Arizona. Particularly enjoyed was the musical entertainment at the piano provided by John L. Mapes, Sparling Meter Company, Los Angeles. Byrl D. Phelps, consulting engineer, San Diego, skillfully handled the program as toastmaster for the dinner.

President Harold W. Yost presided over the Saturday technical program. R. M. Cushing, of Headman, Ferguson, and Carollo, consulting engineers, opened the program by discussing the "Buckeye Sewerage System." A description of the Mesa, Ariz., water supply, by John Hoover, city engineer, Mesa, followed.

Of particular interest to the Association was the paper which discussed "Arizona's Groundwater Resources," by S. F. Turner, U. S. Geological Survey, Tucson, and the illustrated review of the Arizona-California controversy over the Colorado River diversion problem. This review was entitled "Muddy Water—and How It Got That Way," and was ably presented by Milton G. Sanders, vice president, Central Arizona Light and Power Company, Phoenix, Ariz.

N. T. Veatch, president, AWWA, was the honor guest and speaker at the Saturday luncheon. Ladies attending the Conference were guests of the Association at the luncheon.

The closing technical session followed the annual business meeting. Clark Webb, district manager, Pacific States Cast Iron Pipe Company, recounted the economics of "Double Mains" for installation in paved or unpaved streets. Shell Oil Companys' color film on simple hydraulics, "Harnessing Liquids" was interesting and in-

structive. Another session of the very popular "Operators Roundup" and the general discussion of the technical papers concluded the afternoon session.

The dinner dance of the conference, featuring the ritualistic conclave of the "Select Society of Sanitary Sludge Shovelers," was held at the Cobre Valle Country Club and closed a day of busy activity. The Conference was concluded with the Sunday morning inspection tour of the Inspiration Consolidated Copper Company properties.

George W. Marx, Chief Sanitary Engineer, Arizona State Health Department, was selected by the Awards Committee for the FSWA Kenneth Allen Award in recognition of his "outstanding leadership in administration and membership activity" in the Arizona Sewage and Water Works Association.

Officers elected for 1948–49 were:

President: John W. Rausher, Tucson, Ariz.
1st Vice President: A. Anton Frederickson, Prima, Ariz.
2nd Vice President: George W. Marx, Phoenix, Ariz.
Secretary-Treasurer: Mrs. Helen Rotthaus, Phoenix, Ariz.
FSWA Director: Ruskin T. Gardner, Los Angeles, Calif.

HELEN ROTTHAUS,
Secretary-Treasurer

MONTANA SEWAGE WORKS ASSOCIATION

Fourth Annual Meeting

Livingston, Montana, April 8, 1948

The Fourth Annual Meeting of the Montana Sewage Works Association was held at the Murry Hotel, Livingston, Mont., April 8, 1948. Fifty-four members and guests were in attendance.

Chairman Winebanna opened the meeting and called for the reports of the officers and standing committees. F. F. Palmer, city engineering, Forsyth, reported for the committee on the "Design, Construction, and Maintenance of Sanitary Sewer Systems in Montana." The committee was continued for further study of the problem. Dean W. H. Cobleigh and H. B. Foote reported on the February, 1948 school for Water and Sewage Works Operators and Managers. The Association expressed the desire that the school be continued.

The afternoon session was opened by a motion picture on the sanitary fill methods of garbage and refuse disposal. Dr. E. R. Dodge, Professor of Civil Engineering, Montana State College, reviewed "Modern Methods of Sewage Treatment." The highlight of the session was FSWA Executive-Secretary Wisely's illustrated talk on "Design of Sewage Plants with Special Reference to Operation Details." An interesting presentation of the water supply and pollution problems of the Big Horn River was given by L. O. Williams, State Sanitary Engineer of Wyoming.

At the conclusion of the formally prepared part of the program William H. Cobleigh, Dean Emeritus of Engineering, Montana State College, was presented the Kenneth Allen Award for meritorious service to the Association. Dean Cobleigh responded by describing some of his early experiences with and studies of the Montana stream conditions.

The following were elected officers for 1948–49:

Chairman: F. F. Palmer, Forsyth
Vice Chairman: Chester Eyer, Laurel
Secretary-Treasurer: H. B. Foote, Helena

H. B. FOOTE
Secretary-Treasurer

THE MARYLAND–DELAWARE WATER AND SEWERAGE ASSOCIATION

21st Annual Conference

Baltimore, Md., April 15–16, 1948

The 21st Annual Conference of the Maryland-Delaware Water and Sewerage Association was held April 15–16, 1948 at the Lord Baltimore Hotel, Baltimore, Md.

An interesting color moving picture entitled "Water, Water, Everywhere," produced by the American Cyanamid Company, opened the program. This movie illustrated the chemistry of water demineralization by ion exchange.

Other morning program papers were:

"A Community Program of Insect and Rodent Control," by George H. Massey, Jr., Town Clerk, Crisfield, Md.

"The Ortho-Tolidine-Arsenite Test in Chlorine Control," by Harry Faber, The Chlorine Institute.

"Accomplishments and Program of the Maryland Water Pollution Control Commission," by Paul W. McKee, Exec. Secretary.

Jim Engle was leader of the popular "Operators Hour" which opened the afternoon session. Current operation and maintenance problems were given a thorough airing during the session. C. V. Joyce, Washington Suburban Sanitary District, included a fine color movie in his talk on "Trash and Garbage Incineration." Another aspect of the waste disposal problem was brought home to the sewage works operators when Ralph E. Fuhrman, superintendent, Blue Plains sewage treatment plant (Washington, D. C.), gave his paper "Municipal and Individual Garbage Grinding."

The annual business meeting followed the technical program. George S. Russell, FSWA President, presented Federation greetings to the Conference and briefly discussed current Federation activities. George Symons, associate editor, *Water and Sewage Works,* conveyed to the session the greetings and best wishes of Linn Enslow, AWWA president, who was unable to attend the conference.

Main items of business were: (1) adoption of a resolution calling for the starting of an operators short course, and (2) changing of the constitution and by-laws so that the association would operate on a fiscal year. The following officers were elected for 1948–49:

President: R. R. C. Willson, Hagerstown

First Vice-President: A. A. Bailey, Baltimore

Second Vice-President: R. E. Fuhrman, Washington, D. C.

Secretary-Treasurer: Miss E. V. Gipe, Baltimore

The annual dinner-dance and entertainment was very much enjoyed by all.

The April 16 morning session was opened by R. C. Willson, first vice-president, who presented the program speakers. The first of these was Thomas S. Cassedy, Whitman, Requardt and Associates, whose illustrated paper presented the "Practical Design and Construction of Storm Drains for the Small City."

Other papers on the morning program were:

"How Housing Law Enforcement Works," by G. Yates, Chief, Housing Division, Baltimore City Health Department.

"How to Find Leaks in the Small City without Using the Pitometer," by Homer Beckworth, The Pitometer Company.

The Conference closed with a dis-

cussion of the design and construction of the Patapsco River water tunnel and an inspection trip into the tunnel, which is under construction.

MISS E. V. GIPE,
Secretary-Treasurer

PACIFIC NORTHWEST SEWAGE WORKS ASSOCIATION

1948 Annual Meeting

Boise, Idaho, May 12–13, 1948

The 1948 Annual Meeting of the Pacific Northwest Sewage Works Association was held at the Boise Hotel, Boise, Idaho, on May 12–13, 1948, with 144 members and guests attending the sessions.

President H. C. Clare, Chief Sanitary Engineer of the Idaho State Health Department, opened the Wednesday morning session and introduced Mayor Potter P. Howard, of Boise, who welcomed the association's members to Boise. The remainder of the morning session was devoted to technical discussions presided over by Kenneth H. Spies, first vice president of the association.

"Status of Water Pollution Control in the Pacific Northwest" was discussed by the following state pollution control representatives who gave brief summaries of current water pollution control activities of their agencies.

British Columbia—Reginald Bowering, Public Health Engineer, Provincial Board of Health, Victoria, B. C.

Idaho—Mark R. Kulp, State Reclamation Engineer and Chairman, Idaho Water & Stream Utilization Committee, Boise, Idaho.

H. C. Clare, Director, Division of Public Health Engineering, Idaho State Department of Public Health, Boise, Idaho.

Oregon—Curtis M. Everetts, Jr., Secretary and Chief Engineer, Oregon State Sanitary Authority, Portland, Ore.

Washington—Emil C. Jensen, Chief, Division of Public Health Engineering, Washington State Department of Health, Seattle, Wash.

Wallace W. Bergerson, Acting Chief Engineer, Washington State Pollution Control Commission, Olympia, Wash.

Problems of sewage works financing in the Northwest states were exceptionally well covered by the forum on "Methods of Finance for Municipal Sewage Works Construction," which featured the following speakers:

G. D. Hall, Consulting Engineer, Yakima, Wash.

Sherman Ellsworth, Seattle, Wash.

Robert E. Smylie, Attorney General, Boise, Idaho.

Wendell H. Smith, Consulting Engineer, Preston, Idaho.

Deane Seegar, City Manager, Eugene, Ore.

C. R. Tulley, executive vice president, Northwest Canners Association, Portland, Ore., closed the morning session with an industrialist's view of pollution control in his presentation of "Problems of Waste Disposal in the Canning Industry."

Emil C. Jensen, second vice president, presided over the Wednesday afternoon technical program during which the following papers were presented:

"Developments in the Disposal of Waste Sulfite Liquors," by Dr. R. S. Hatch, director of research, Pulp Division, Weyerhaeuser Timber Company, Longview, Wash.

"The Boise Sewerage Project," by Louis R. Howson, consulting engineer, Chicago, Ill.

"Pollution of Irrigation Waters," by C. T. Wright, sanitary director,

U. S. Public Health Service, Denver, Colo.

"Observations on Garbage and Liquid Sludge Disposal in the Midwest," by James C. Howland, consulting engineer, Corallis, Ore.

The Association's annual dinner meeting, Wednesday evening, was devoted to a business session and the consideration of committee reports. Especially gratifying was the report of the Membership Committee who reported a membership increase of 44 during 1947–48. Federation Director C. M. Howard presented FSWA President George S. Russells' regrets at not being able to attend the meeting, and read to the association Mr. Russells' letter describing Federation plans and activities for 1948. Following election of officers a motion picture entitled "The Story of the Snake River" was enjoyed by all present.

The Operators' Forum Breakfast constituted the Thursday morning technical program. Over 56 members and guests participated in the interesting, and at times lively, discussions of operation problems. The preparation and planning of the discussion leaders contributed greatly to the success of the spirited exchange of ideas and experiences. Discussion leaders were: Joe Latimore, Idaho State Health Department; Elmer Mathews, Ellensburg, Wash., sewage works operator; William P. Hughes, Lewiston, Idaho, city engineer; Glen Davis, Jr., Gowen Field, Idaho, sewage works operator; C. I. Goff, Preston, Idaho, city manager; V. L. Goodnight, Corvallis, Ore., city engineer.

Officers elected for the year 1948–49 were:

President: Kenneth Spies, Portland, Ore.

First Vice President: Emil C. Jensen, Seattle, Wash.

Second Vice President: W. P. McNamara, Seattle, Wash.

Secretary-Treasurer: William P. Hughes, Lewiston, Idaho.

WILLIAM P. HUGHES,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Georgia Sewage Works Assn.	Georgia Inst. of Technology, Atlanta, Ga.	Sept. 22–24, 1948
South Dakota Water & Sewage Works Conference	Carpenter Hotel, Sioux Falls, S. D.	Sept. 30–Oct. 1, 1948
West Virginia Sewage and Ind. Wastes Assn.	Stonewall Jackson Hotel, Clarksburg, W. Va.	Sept. 30–Oct. 2, 1948
Virginia Ind. Wastes & Sewage Works Assn.	Hotel George Mason, Alexandria, Va.	Oct. 7–8, 1948
Arizona Fall Conference	Hotel Westward-Ho, Phoenix, Ariz.	Oct. 15–16, 1948
Federation of Sewage Works Associations	**Statler Hotel, Detroit, Mich.**	**Oct. 18–21, 1948**
Michigan Sewage Works Assn.	Statler Hotel, Detroit, Mich.	Oct. 18–21, 1948
Missouri Water & Sewage Conference	Hotel Governor, Jefferson City, Mo.	Oct. 24–26, 1948
North Carolina Sewage Works Assn.	George Vanderbilt Hotel, Asheville, N. C.	Nov. 8–10, 1948

Federation Affairs

TWENTY-FIRST ANNUAL MEETING PREVIEW

Hotel Statler, Detroit, Mich., October 18–21, 1948

★

IN CONJUNCTION WITH
TWENTY-THIRD ANNUAL MEETING OF
THE MICHIGAN SEWAGE WORKS ASSOCIATION

★

Featuring a technical program of unusual diversity and timeliness, the Federation's Twenty-First Annual Meeting promises to surpass all previous meetings in interest and attendance. All of the many local arrangements necessary for a successful convention have received the careful attention of W. M. Wallace and his 40 host committee members of the Michigan Sewage Works Association. Their work, coupled with that of the program committee, insures a meeting of high technical quality and of excellent social and entertainment value. The large and complete manufacturers' exhibit will add to the interest and enjoyment of the meeting and will provide Federation members an opportunity to view the latest developments in sewage works equipment and supplies.

An extra day has been added to the program this year in order to include all of the features planned for the Twenty-First Annual Meeting.

THE PROGRAM

MONDAY, OCTOBER 18

Morning

Registration—Convention Floor Foyer.

Inspection of Exhibits—Exhibit Hall.

Twenty-First Annual Meeting Called to Order by President George S. Russell.

Welcome to Detroit

Hon. Eugene I. Van Antwerp, Mayor, City of Detroit.

Moving Picture—"Taken for Granted"

Compliments West Middlesex Main Drainage, London, England.

Plans and Activities of the USPHS in Relation to Water Pollution Control Act

Carl E. Schwob, Director, Water Pollution Control Section, USPHS.

Afternoon

USPHS Survey of the Detroit River

M. LeBosquet, Jr., Sanitary Engineer, USPHS.

Sewage Treatment and Waste Disposal in Ontario

Dr. A. E. Berry, Director, Sanitary Engineering Division, Ontario Department of Health.

Problems of Waste Disposal from Atomic Energy Operations

Arthus E. Gorman, Sanitary Engineer, U. S. Atomic Energy Commission.

Discussion: Lloyd R. Setter, Sanitary Engineer, Tennessee Valley Authority.

Evening

RECEPTION—ENTERTAINMENT—Grand Ball Room

TUESDAY, OCTOBER 19

Morning

Mechanisms of Hydrogen Sulfide Production
Rolf Eliassen, Professor of Sanitary Engineering, New York University.

A System of Bio-Precipitation of Organic Matter from Sewage
Daniel A. Okun, Teaching Fellow in Sanitary Engineering, Harvard University.

Discussion: Dr. F. W. Mohlman, Director of Laboratories, The Sanitary District of Chicago.

Effects of Synthetic Detergents on Sewage Treatment Processes
Dr. Willem Rudolfs, Chief, Department of Sanitation, Rutgers University.

Mathematical Aspects of Bulking Activated Sludge
L. S. Kraus, Chemist, Peoria (Ill.) Sanitary District.

Discussion: Earnest Boyce, Professor of Sanitary Engineering, University of Michigan.

Noon

ANNUAL FEDERATION LUNCHEON

Address: "Let's Be Realistic About Pollution"
Kenneth L. Reid, Executive Secretary, Izaak Walton League of America.

Afternoon

The Industrial Wastes Forum

Dr. F. W. Mohlman, Leader

Effluents from Chemical Manufacture at Bound Brook, N. J.
Dr. V. L. King, Technical Director, Calco Chemical Division, American Cyanamid Co.

Dairy Waste Disposal
E. F. Eldridge, Research Professor, Michigan State College.

Indices of Stream Pollution
Don E. Bloodgood, Professor of Sanitary Engineering, Purdue University.

Wastes from Chemical Manufacture
R. W. Hess, Chemist, National Aniline Division, Allied Chemical and Dye Corporation.

Evening

MICHIGAN SEWAGE WORKS ASSOCIATION DINNER AND BUSINESS MEETING—Prince Edward Hotel, Windsor, Canada.

WEDNESDAY, OCTOBER 20

Morning

Factors Affecting Efficiency of Activated Sludge Sewage Treatment Plants
William E. Stanley, Professor of Sanitary Engineering, Massachusetts Institute of Technology.

Biology of Sewage Treatment
James B. Lackey, Editor, Medical and Scientific Division, Blakiston Publishing Company.

Sewer System Operation and Maintenance Practices at Milwaukee
Lloyd D. Knapp, Superintendent, Bureau of Sewers, City of Milwaukee.

Design and Operation of the Detroit Sewage Treatment Plant
Fred H. Burley and W. M. Wallace, respectively, Engineer of Sewage Treatment and Superintendent of Filtration and Sewage Treatment, City of Detroit.

Afternoon

Inspection Trip
Detroit Sewage Treatment Plant.
Dearborn Sewage Treatment Plant.

Evening

ANNUAL FEDERATION DINNER AND DANCE—Grand Ball Room

THURSDAY, OCTOBER 21

Morning

'The Operators' Forum

Ralph L. Fuhrman, Leader

Annual Operation Reports.
Corrosion Problems.
Mechanical and Electrical Maintenance.
Public Relations.
Paints and Protective Coatings.
Sewer Ordinances.

Noon

Adjournment.

TECHNICAL PROGRAM COMMENTS

Although the interests of Federation members are many and varied, the Program Committee, under the leadership of F. W. Gilcreas, has developed a well-rounded and diversified technical program. Current stream pollution and waste treatment problems have been given special consideration in planning the program and subjects relating to both technical and practical interests of the Federation have been well balanced.

The newer aspects of waste treatment have also been included for discussion, reflecting the progressive outlook and expanding interests of the Federation. Presentation of atomic energy waste disposal problems and other equally new and important subjects will keep Federation members abreast of late developments in the field.

An innovation in this year's program is the Industrial Wastes Forum, under the leadership of Dr. F. W. Mohlman, Chairman, FSWA Industrial Wastes Committee, which will feature discussions of especial interest and timeliness in this important area of waste treatment. Without doubt this new program feature will take its place along with the Operators' Forum as a perennial

program headliner at future annual meetings. The Operators' Breakfast, with Ralph E. Fuhrman, of Washington, D. C., as leader, will again justify its allotment of an entire morning of program time. Topics selected for these forums will provide unlimited opportunity for active discussion and the worth while exchange of experiences and ideas.

The 1948 technical program offers outstanding papers and discussions of value and interest to everyone in the field.

SOCIAL FUNCTIONS

The well-laid plans for the social functions for the Twenty-First Annual Meeting guarantee wonderful times of fun and fellowship for all. Opening the social program will be the Reception-Entertainment to be held Monday night. As an informal reception and mixer, this event will provide an excellent opportunity to greet old friends. A family entertainment hour will follow the reception; both professional and selected home talent will be featured. The manufacturers' exhibit will be open during this evening.

The Federation Luncheon will present one of the country's leading proponents of conservation and stream pollution control, Kenneth L. Reid, Executive Secretary of the Izaak Walton League of America, speaking on the subject: "Let's be Realistic About Pollution." Special tables will be reserved at the luncheon for the Quarter Century Operators' Club.

Highlight of the social program will be the Annual Federation Dinner and Dance. A feature of every annual meeting, the Dinner and Dance is arranged for Wednesday evening. Music and entertainment suitable for the occasion is planned for the dinner hour, which will be followed by the presentation of the Federation's annual awards. There will be no other official business or speeches. Dancing to one of Detroit's finest orchestras will affort pleasurable entertainment for the remainder of the evening. As usual, dress will be optional.

The Michigan Dinner and Business Meeting Tuesday night has been arranged to provide a social and business get-together for the host association. This event will be limited to members of the Michigan Sewage Works Association and guests. It will be held at the Prince Edward Hotel, Windsor, Canada. For other Federation members the evening has been left open for entertainmnt of their own choice.

LADIES' ENTERTAINMENT

Entertainment for the ladies attending the Annual Meeting will start with a "get aquainted" bridge party in the English Room Monday afternoon.

A special treat is planned for Tuesday—luncheon at the famous Dearborn Inn, followed by either a tour of beautiful Greenfield Village (early American restoration), or a visit to the Thomas A. Edison museum. If time permits, a drive through the Henry Ford gardens will complete the afternoon.

On Wednesday, the Ladies' Committee will make arrangements for those desiring to visit the Hudson Department Store Style Show, which is featured each week during the luncheon hour. Wednesday afternoon the lovely Belle Isle and Grosse Point sections along Detroit's beautiful water front will be visited by bus, along with other places of interest. Ample time has been allowed for visiting Detroit's many shops and stores!

The Ivory Room has been reserved for the use of the ladies attending the meeting and will serve as their headquarters.

INSPECTION TRIPS

A break in the technical program has been provided for Wednesday afternoon so that all may have the opportunity of visiting the Detroit and Dearborn sewage treatment plants. Transportation and guide service have been arranged which will make the group inspection of these interesting plants an enjoyable interlude in the convention program.

On Thursday, for those who are primarily interested in industrial waste treatment, arrangements have been made for an all-day tour of the Dow Chemical Company wastes treatment plant at Midland, Mich., as well as other installations enroute.

EXHIBITS

Rivaling the technical program in interest and variety, the display of sewage works equipment and supplies planned for the Twenty-First Annual Meeting will be outstanding. All available exhibit space was allocated by the Water and Sewage Works Manufacturers' Association before mid-July. Thirty manufacturers and suppliers will use fifty-two booths in displaying their products. Informed company representatives will supplement the exhibits of improved and new equipment with first-hand technical data.

The following companies will be represented in the exhibit:

American City Magazine.
American Well Works
Builders-Providence, Inc.
Carter Company, Ralph B.
Chain Belt Company.
Chicago Pump Company.
Cloroben Corporation.
Dorr Company, Inc.
Engineering News-Record.
Flexible Sewer-Rod Equipment Company.
General Electric Company.
Hardinge Company.
Hersey Manufacturing Company.
Infilco, Inc.
Jeffrey Manufacturing Company.
Johns-Manville.
Koppers Company (Tar Products Division).
Link-Belt Company.
Lock Joint Pipe Company.
Nichols Engineering and Research Corporation.
Pacific Flush-Tank Company.
Public Works Magazine.
Sewage Works Engineering.
Simplex Valve & Meter Company.
Vapor Recovery Systems Company.
Walker Process Equipment, Inc.
Wallace & Tiernan Company, Inc.
Water & Sewage Works.
Worthington Pump & Machinery Corp.
Yeomans Brothers Company.

REGISTRATION INFORMATION

A fee of $10.00 will cover registration, technical session privileges, the Monday Reception-Entertainment, and the Wednesday Dinner and Dance. For the ladies, the same fee will include all special ladies' entertainment events as well as the Reception and Annual Dinner. Tickets for the Annual Federation Luncheon on Tuesday will be $3.00, and for the Wednesday Inspection Trip will be $1.50. In separate tickets, the registration fee (required for attendance of technical sessions) will be $4.00, the Reception-Entertainment $2.00, and the Dinner and Dance $6.00.

HOTEL ACCOMMODATIONS

Ample hotel accommodations have been arranged for Federation members and guests attending the Detroit meeting. Reservations, however, must be made by October 4, 1948, since all rooms now allocated for those attending the Federation meeting will be released to the general public at that time.

Requests for reservations should be sent directly to the Hotel Statler, convention headquarters hotel. A schedule of room rates is indicated on the reservation request card which has been sent to all Federation members.

Although the Statler has made a generous allocation of rooms for the Federation meeting, it will not have accommodations for everyone who will attend the convention. When all allocated space at the Hotel Statler has been assigned, requests for reservations will be referred to the Book-Cadillac or other first-class hotels.

LOCAL ARRANGEMENTS COMMITTEE

The local arrangements committee, under the chairmanship of W. M. Wallace, is comprised of the chairmen of the following sub-committees:

Registration Committee: G. R. Thompson, chairman; C. L. Palmer; M. F. Wagnitz; W. C. Hirn; L. Leonhard.

Hotel Arrangements Committee: F. G. Legg, chairman; R. Chapin; M. Hilbert; N. Herda; A. Dempster.

Finance Committee: W. E. Smith, chairman; J. S. Perry; A. Hubbell; V. Anderson; J. W. Orton.

Inspection and Transportation Committee: Leroy Smith, chairman; F. Burley; A. T. Kunze; C. A. Habermehl; J. E. Cooper; M. Groen.

Entertainment Committee: M. Groen, chairman; F. W. Dubois; E. Dingler; L. A. Danse; G. McGride; J. W. Trautner.

Ladies' Entertainment Committee: Mrs. V. Anderson, chairman; Mrs. L. G. Lenhardt, Mrs. E. Boyce; Mrs. W. M. Wallace; Mrs. F. G. Legg; Mrs. F. C. Burley; Mrs. J. W. Orton; Mrs. Geo. Thompson; Mrs. L. S. Smith; Mrs. M. Hilbert.

Local Host Committee: W. E. Sheppard, chairman; E. Boyce; D. Pierce; N. Damoose; L. Oeming; L. G. Lenhardt; J. W. Hepler; H. C. Potts; W. C. Dalee; M. F. Adams; E. F. Eldridge; R. A. Green; B. W. McCord.

Book Review

Soil Mechanics in Engineering Practice. By Karl Terzaghi and Ralph Peck. John Wiley & Sons, New York. First Edition, 1948. 535 pages. Price $5.50.

This book combines lucid discussions of both principles and practice in soil mechanics. It offers definite directions by which the engineer can judge the extent to which soil mechanics can profitably be used on a given job.

The book is divided into three parts:

A. Physical Properties of Soils (119 pages).

B. Theoretical Soil Mechanics (136 pages).

C. Problems of Design and Construction (280 pages).

Parts A and B are short but contain all that engineering students and the average engineer need to know about soil mechanics at the present time.

The heart of the book is Part C. The treatment of the subject in Part C is indicated by the following exerpt from the preface: "On the overwhelming majority of jobs no more than an approximate forecast (of soil strata) is needed, and if such a forecast cannot be made by simple means it cannot be made at all. If it is not possible to make an approximate forecast, the behavior of the soil must be observed during construction, and the design may subsequently have to be modified in accordance with the findings."

The authors are widely known in their field, the senior author being generally credited with having founded the science of soil mechanics and introducing it into this country. Both men have had wide consulting experience.

The book contains many references and provides a well developed author and subject index. No direct reference is made in the book to the problems of sewage works construction although design and construction engineers will find much of value in it.

S. C. Martin

Reviews and Abstracts*

Report of Water Pollution Research Board, 1946. Department of Scientific and Industrial Research (Great Britain). 39 pp. May, 1947.

This report devotes 10 pages to sewage problems, 14 pages to industrial wastes, and 3 pages to polluting effects of sewage and industrial wastes.

Biological filtration experiments continued at Minworth (Birmingham, Tame and Rea District Drainage Board) on treatment of settled sewage by alternating double filtration (ADF) and filtration by recirculation of settled effluent. From July, 1944, to May, 1945, the rates of filtration per cu. yd. per day in Imp. gal. were: with ADF, from 275 to 294; with recirculation of effluent, 209 to 240.

The B.O.D. applied ranged from 150 to 210 p.p.m. The ADF effluent ranged from 6 to 18 p.p.m. With recirculation, the effluent ranged from 8 to 24 p.p.m. From June, 1945, to May, 1946, the ADF operated for two filters together at rates from 168 to 199 Imp. gal. per cu. yd. per day. The recirculation operated at rates from 210 to 222 Imp. gal. per cu. yd. per day. The B.O.D. applied ranged from 165 to 210 p.p.m. The B.O.D. in the effluent from the ADF ranged from 9 to 17 p.p.m., and from recirculation, 13 to 22 p.p.m. Thereafter experiments were made with rates varied in each 8-hour period daily, 50 per cent below and 50 per cent above the third period.

Semi-scale tests at Coventry on settled sewage (B.O.D. 315 p.p.m.), with rates in Imp. gal. per cu. yd. per day averaging—single filtration 60, ADF 120, and recirculation 120, produced somewhat lower BO.D. (34; 31; and 31 p.p.m.) and somewhat higher ammonia as N (25; 28; and 31 p.p.m.) in ADF and recirculation.

Tests at Minworth on settled sewage, treated by bioflocculation (short period activated sludge) applied to a biological filter at rates from 160 to 205 gal. per cu. yd. per day produced a fair effluent (B.O.D. 17 to 27 p.p.m.), where normally 60 gal. per cu. yd. per day of settled sewage would be applied.

Investigation on waste waters from farm premises indicated an equivalent of from 1 to 4 persons per head of cattle.

In the control of filter flies (*Anisopus*), DDT and Gammexane were tried on a scale at Minworth, using applications of an emulsion containing from 10 to 250 lb. of DDT per acre and 0.5 to 10 lb. of Gammexane per acre. A considerable reduction of flies was obtained with a single application of 1 lb. of Gammexane per acre, or 50 lb. of DDT per acre.

In the control of *Psychoda* during 6 weeks, a single dose of 1 lb. of Gammexane per acre or 5 lb. of DDT per acre was effective.

This confirmed laboratory tests that Gammexane was equally toxic to *Anisopus* and *Psychoda*, whereas DDT is ten times as toxic to *Psychoda* as to *Anisopus*.

Data are also given on the reduction of bacteria in filter effluents (both single and ADF) on plate counts at 20, 30, and 37° C., and *B. Coli*. The percentage reduction from a single filter was greater in the warmer months. The reductions with the single filter were greater than for the ADF.

An investigation of waste waters from an engine factory, containing oil, on a laboratory scale indicated the value of flotation tanks (four at 1,100 Imp. gal.) followed by treatment with aluminum sulfate and sulfuric acid (four at 1,100 Imp. gal.). All water containing oil should be collected in a common outfall to an oil interceptor (in this case two rectangular tanks 23,000 Imp. gal. each) suitably equipped with transverse baffles.

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* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

Corrosion from beet sugar wastes of low pH was also investigated, to determine value of chlorine as a bactericide and lime as a neutralizer. Lime was difficult to control. Chlorine was effective in reducing bacteria and minimizing corrosion. Reuse of process water had no adverse effect on diffusion, first—carbonation, or, second—carbonation juice, but may have increased corrosion slightly.

In the manufacture of DDT, some difficulties resulted in disposal of waste liquids in that acidic wastes damaged a sewage disposal works. Three factories were examined. In one, dilution (4 parts spent acid to 100,000 parts sewage) was sufficient. In two others, all waste waters were collected and taken to sea. Apparently waste hypochlorite liquor was the principal cause of interference with percolating filters, being toxic to various organisms prevalent, whereas waste wash water from DDT manufacture and neutralized waste hydrochloric acid were not toxic. The absorption of waste chlorine by caustic soda was recommended, producing a salable sodium hypochlorite.

The treatment of waste waters containing cyanide is discussed, the use of ferrous sulfate and lime being superseded by chlorine and alkali.

The effect of continuous aeration on bacterial oxidation of organic matter produces more complete oxidation of the substrate.

The polluting effects of sewage and industrial wastes on the River Avon were also examined. Fluctuations in bacterial counts were found, with increases due to rain. The toxicity of chlorinated sewage effluents was traced to thiocyanates present, which increased the required period of aeration in an activated sludge plant. Small concentrations of phenol were toxic in the absence of chlorine.

LANGDON PEARSE

Report, Rivers Department, City of Manchester (England), for Two Years Ended March 31, 1946 (78 p). (Summarized in *The Surveyor,* **107**, 133 (Mar. 12, 1948)).

The total contributory population in 1946 was 823,000, of which all but 47,000 is treated at Davyhulme. The work of the Department includes control of rivers and trade effluents, and collapsed walls and culverts. The estimated trade wastes are 16 m.g.d. (Imp. gal.) or 20 m.g.d. (U. S. gal.). Of this, about 14 m. g.p.d. (Imp. gal.) is received at Davyhulme, contained in 62,175,000 g.p.d. (Imp. gal.) of sewage in 1945–1946. The respective per cents treated were:

Per Cent		Treatment
1944–1945	1945–1946	
15.6	13.6	Settling in storm water tanks
8.2	7.9	Settling
5.5	5.2	Settling; primary contact
31.7	29.7	Settling; primary and secondary contact
1.1	1.1	Settling; bio-aeration
2.1	2.0	Settling; Simplex aeration
35.8	40.5	Settling; activated sludge diffused air

The average amount of air per Imp. gal. used in the works was 0.79 cu. ft. in 1944–1945 and 0.82 cu. ft. in 1945–1946. Renovation of diffusers was continued. For a while, aeration units 4 and 5 were operated without diffusers. Corrosion of air pipes and cast iron plate boxes have been severe.

Detritus is dumped on disused storm beds. Sedimentation, storm water, and digested sludge is dumped at sea or disposed of on land or lagoons. Densified activated sludge is disposed of on land, or on draining beds or lagoons. About three-quarters of the excess activated sludge is pumped into the raw sewage and settled. Heat-controlled digestion has an 11 or 12 day period. Experiments indicated a longer period was not warranted.

Research work covered flocculation of sewage with surplus activated sludge. Experiments were also made with a semi-scale Dorr-Oliver vacuum filter on dewatering sludge by coagulation and filtration. Tests on a small scale were made on drying with infra-red. The activated sludge contained about 6 per cent N on a dry basis. Apparently about 12.9 per cent ferric chloride was used for sludge conditioning.

The data indicate that results at Man-

Analysis of Raw Sewage, Sedimentation Effluent, and Effluent of Secondary Contact Beds

Determination	Raw Sewage		Settled Sewage		Secondary Contact Beds	
	1944–1945 (p.p.m.)	1945–1946 (p.p.m.)	1944–1945 (p.p.m.)	1945–1946 (p.p.m.)	1944–1945 (p.p.m.)	1945–1946 (p.p.m.)
Ammoniacal N	26.0	29.0	26.5	29.1	18.3	22.5
Alb. N	6.6	8.4	5.4	6.1	2.3	3.2
Chlorine in chlorides	212	228	212	244	176	187
B.O.D.	171	208	149	163	47.3	56.3
Suspended matter						
Volatile	124	131	44	45	—	—
Mineral	61	67	52	46	—	—
Total	185	198	96	91	33	36
Nitrite N	—	—	—	—	0.22	0.18
Nitrate N	—	—	—	—	3.0	3.5

Average Results of Operation of Activated Sludge at Davyhulme
Year ended March 31, 1945

Determination	Bioaeration*	Simplex Aeration	Diffused Air		
			Unit 1	Unit 2	Units 3–7
Settled sewage (Imp. m.g.d.)	0.625	1.224	4.654	4.706	11.812
Detention period (hours)	17.7	13.1	7.1	7.0	11.2
Average hp. per m.g. (Imp.)	44.6	26.7	25.0	21.7	39.5
Effluent (p.p.m.):					
Ammoniacal N	21.2	21.2	21.2	21.1	21.5
Albuminoid N	1.5	1.45	1.5	1.5	1.7
Nitrous N	0.2	0.25	0.2	0.2	0.1
Nitric N	1.4	1.2	1.2	1.3	1.2
Cl in chlorides	209	210	211	212	210
B.O.D.	9.0	9.5	10.4	9.9	12.2
Suspended solids	16	16	16	17	21

* Haworth system.

Average Results of Operation of Activated Sludge Plants at Davyhulme
Year ended March 31, 1946

Determination	Bioaeration*	Simplex Aeration	Diffused Air		
			Unit 1	Unit 2	Units 3–7
Settled sewage (Imp. m.g.d.)	0.676	1.237	4.557	4.585	16.035
Detention period (hours)	16.3	12.9	7.3	7.2	8.3
Average hp. per m.g. (Imp.)	40.6	26.1	23.6	23.5	26.8
Effluent (p.p.m.):					
Ammoniacal N	23.1	23.5	23.9	23.6	24.1
Albuminoid N	1.8	1.7	1.8	1.8	1.9
Nitrous N	0.15	0.15	0.15	0.15	0.15
Nitric N	1.3	1.3	1.2	1.3	1.2
Cl in chlorides	215	215	218	214	215
B.O.D.	13	12.7	14.2	13.8	14.6
Suspended solids	18	17	19	19	21

* Haworth system.

chester are generally inferior to those obtained at American plants.

LANGDON PEARSE

Waste Waters Discharged from an Abattoir. BY H. E. JONES. *The Surveyor,* 107, 159–160 (March 26, 1948).

There appears to be an increasing tendency to centralize the meat industry. This tendency accentuates the problem of slaughterhouse waste disposal. This is particularly true in rural areas where the wastes cannot be mixed with large volumes of domestic sewage.

Much has been published in the United States on the character of slaughterhouse and packinghouse wastes. The amount of polluting matter discharged for a given number of animals varies as between different establishments, being greater, in general, at the smaller plants where recovery is less efficient. In an investigation on the pollution of the Ohio River it was found that the combined wastes from slaughterhouses had an oxygen demand of about 1,000 p.p.m. and a population equivalent of about 18 per "hog unit" killed per day. A "hog unit" is calculated on the assumption that the waste water from one mead of full grown cattle is equivalent to that from 2½ pigs, sheep, or calves. Where meat products are prepared and packed the population equivalent was about 24 per hog unit killed per day.

Cattle, sheep and pigs are killed at the establishment where this investigation was made. Some material is brought in from other slaughterhouses for processing. The premises include a bakehouse where pies, sausages, puddings and other products are prepared. Materials unfit for human consumption are processed into feed and fertilizer in a byproducts plant.

The following tabulation lists some of the results of the investigation.

Sample	Flow per Day (Imp. gal.)	Susp. Solids (p.p.m.) (a)	5-day B.O.D. (18.3°C.) (p.p.m.) (b)	Ammonia (As N) (p.p.m.) (b)	Equivalent Volume of Domestic Sewage (c)	Daily Output During Period of Study
Combined Wastes:						
Main waste	6,972	855	1,380	91	32,980	75 hog units
Condenser waste from drying of blood and offal	5,680	27	40	17	910	18 cwt. of clotted blood and 15 cwt. of offal
Wastes from separate sections:						
Slaughtering	4	1,122	2,830	119	—	—
Dehairing of pigs	420	264	670	87	1,127	14 pigs
Drainings from coagulated blood before drying	—	2,180	24,670	3,050	—	—

(a) Unsettled sample.
(b) After settling 1 hour in laboratory.
(c) Calculated on the basis of 250 p.p.m. 5-day B.O.D. for average settled domestic sewage.

T. L. HERRICK

The Treatment of Huddersfield Sewage on Percolating Beds Filled with Special Tiles. BY H. H. GOLDTHORPE AND J. NIXON. A preprint of a paper presented to the North Eastern Branch of the Institute of Sewage Purification (British) on April 9, 1948 (16 pages, mimeographed).

When sewage trickles over the medium of a new trickling filter little or no purification takes place until a coating of growth has established itself on the surfaces. As sewage flow continues purification improves and growth increases. This growth, unless kept in check, may become so great as to fill the voids of the

medium, prevent aeration, and stop the purification process. Therefore, conditions must be adjusted so as to maintain a film yet not allow it to become so great as to clog the bed.

There appears to be a minimum period of time necessary for a definite amount of film growth to purify a certain volume of sewage, and increased growth on the media surfaces gives increased detention and increased purification provided aeration is not impeded. To improve the factors of aeration and detention attempts were made to form beds of manufactured fillings having properties which offered less aeration impedance and greater water-holding capacity.

The following table gives the properties of a number of conventional materials with which beds are filled, together with the properties of artificial fillings used in the chemical industry for absorption towers and the properties of a special tile, designed for trial in these experiments, which was named "Huddersfield Tile."

A study of the "Huddersfield Tile" was undertaken principally in connection with its use in primary trickling filters where high dosing rates cause greater growths and where detention periods using ordinary media are small. B.O.D. reduction per cu. yd. also requires a higher rate of aeration in filters of this type.

The "Huddersfield Tile" used in these experiments consists essentially of a tray, about ½ in. deep and with a flat rim, standing on three legs. The underside of the tray is curved and falls to the center causing the liquid which overflows the rim to drip on the tile below. A longitudinal recess runs along the underside to serve as a nest for the eggs of the *psychoda*. The depth of the tray can be reduced in manufacture so that in the upper layers of a filter more aeration and less detention is given. The level tile, in a clean condition, with ½-in. deep tray, holds 420 ml. of water and under working conditions with a growth on the rim has a slightly larger holding capacity. With 324 tiles per cu. yd., the holding capacity is nearly 30 gal. or 17.8 per cent. The empty tiles give a per cent void space of 61.6 so that a working bed would have a void space of about 40 per cent.

Experiments were also conducted using

Material	Area (sq.yd./cu.yd.)	Voids (%)	Weight (lb./cu.yd.)	No. of Units Per Cu.Yd.
Coke				
3″	38.1	58	783	729 dumped
Quartz				
6″	18.9	44	2,403	—
3″	38.1	46	2,322	—
2″	56.1	46	2,376	—
½″–1″	150.9	47	2,376	—
1¼″–1¾″	90.0	—	—	—
Crushed stone				
¼″	369	—	—	—
½″	237	—	—	—
¾″	159	—	—	—
Granite				
1″–3″	70.2	37	2,440	—
Raschig rings				
1″	156.6	58.1	1,342	—
1½″	105.0	68.2	1,104	—
2¼″	68.1	74.9	818	—
Lessing rings				
2″ × 2″	111	95		4,320
1″ × 1″	212	93		35,100
Huddersfield tile	36	61.6	1,539	324

frogged and channelled bricks as the filter medium. Studies were also made on the aeration capacity of the Huddersfield tile. The preliminary experiments with tap water to determine a tile's aeration capacity showed that with water below 50 per cent saturation it was of the order of 7.5 grams of oxygen per sq. meter per day, somewhat better than Sierp's value of 5.0 grams per sq. meter per day for agitated surface aeration.

Results of treatment of settled sewage on an 18 ft. diameter filter, one-half of which was filled with metallurgical coke and the other half with gradually increasing depths of "Huddersfield Tiles," are presented in tabular form. The B.O.D. of the settled sewage varied from about 150 to 281 p.p.m. This was a "chemical" sewage, very resistant to biological oxidation. The dosing rate on the coke side varied from 621 to 1,011 gal. per cu. yd. The B.O.D. of the effluent from the coke side was between 78 and 166 p.p.m. The effluent B.O.D. on the tile side varied from about 110 to 192 p.p.m. for tile depths varying from 2 to 7 feet. The time of contact of the tile half of the bed which had only ¾ of its depth actual tray tiles was more than twice that of coke.

Other types of tiles were tried in 6-ft. columns. Trays were designed to avoid short circuits and with greater water holding capacities, but without any marked improvement.

PAUL D. HANEY

Symposium on New Problems in Sewage Treatment with Special Reference to Synthetic Detergents. Part 1. The Nature of Synthetic Detergents. BY W. H. HILLIER AND S. G. CAMPBELL. Presented at The Institute of Sewage Purification, North Eastern Branch, Feb. 27, 1948.

Almost all early synthetic detergents were sulfonated or sulfated products derived from natural fatty materials such as oleic acid and fatty alcohols. New solvent refining processes in the production of lubricating oils have led to the production of large quantities of aromatic viscous oils, as byproducts, for which outlets were required. "Cracking" to sulfate the long chain olefins gave refined grades of neutralized sulfated oils with good detergent properties which had to be enhanced by proper alkaline additions. They have no reaction with hard water because the calcium and magnesium soaps are soluble in water.

There are many other sulfated oily products which may be used as wetting agents or detergent aids, such as sulfonated naphthenates.

Another type of synthetic detergent is known as anion class of emulsifier or detergent because the active groups are anions. Such detergent is built up from a simple ethylene oxide.

The scouring of textiles with these new agents has the advantage that the dirt is not reprecipitated on the fiber along with the lime soaps as is the case with ordinary soaps. The suds from wool washing bowls may be passed through a centrifuge to skim off a high proportion of lanolin, or the suds may be cracked direct with acid to remove grease.

Wool fat forms a more stable emulsion with synthetic detergent than with soap, and, as a result, the centrifuge is able to separate out the larger fat globules with lower grease recovery than with soap scour. Acid cracking of synthetic detergent wool scour gives a much bulkier coagulation which does not completely separate from the liquors until well cooled, and thereby results in part of the grease being lost. Furthermore, synthetic detergents contribute no oil or fat to the wool grease, hence there is a further reduction in the yield of wool grease, but the cracked grease contains much less fatty acid which may be an advantage.

The quality of cracked grease from synthetic scours is not much different from that produced from soap scours. Very little of the synthetic detergent residue remains in the cracked grease; most of it goes into the effluent. These detergents may cause further trouble in sewage plants.

Treatment with cation form of compounds separates wool fat from synthetic detergent wool scouring liquors by the formation of insoluble products with the anions of sulfuric acid ester salts. This process requires neutralization of alkaline radical in the detergent. The cationic compounds which may be used are: salts of aluminium, ferric iron, onium com-

pounds, and quaternary ammonium compounds. It is not economical to use the organic compounds mentioned, and the only practicable compounds are aluminium and ferric salts.

Part 2. Synthetic Detergents From the Standpoint of Treatment of Domestic Sewage. By C. Lumb and J. P. Barnes.

The authors state that substantial usage of synthetic detergents will result in considerable difficulty in plants treating domestic sewage.

The grease present in sludge produced from domestic sewage is derived from soaps. These soaps react with the hardness of the water to form insoluble calcium and magnesium precipitates of fatty acids. This means that a natural precipitation of considerable magnitude removes materials which would otherwise pass to secondary treatment units. The precipitation of the soap in this manner must also result in the co-precipitation of an additional quantity of other solid matter.

Synthetic detergents are stable to hard waters and therefore instead of the detergent and emulsified impurities being precipitated as with soap, these will pass to the secondary treatment units increasing the solids and oxygen loads. Soap reacting with hard water gave reduction of 40 per cent of the oxygen absorbing materials while synthetic detergents gave much smaller percentages of removal with the same hard water. Use of synthetic detergents on a considerable scale may involve:

1. Extension of the capacity of secondary treatment devices with the production of a greater quantity of secondary sludge and a reduced grease content of primary sludge, with consequent lower yields of gas.

2. An increasing recourse to chemical precipitation. Detergents obtained as by-products from petroleum refining have possibilities of formation of insoluble salts and, hence, of precipitation. The detergent derived from ethylene oxide condensation being nonionic is not likely to be precipitated. Concentrated and neutralized solution of the former type of detergent was rendered less stable by ferric and aluminum salts and by strong acids, but the latter type of detergent forms insoluble complexes only with lead acetate and tannic acid. Sewage containing these detergents behaved differently than the pure substances. Aluminum, ferric, or chlorinated copperas gave the best precipitation with the detergent derived from petroleum products, as well as with ethylene oxide type of detergent.

Part 3. Synthetic Detergents From the Standpoint of the Treatment of a Sewage Containing Wool and Yarn Scouring Liquors. By W. H. Hillier and C. C. Beedham.

Various proportions of sewage and wool suds "cracked" with sulfuric acid in the normal way gave a low percentage of purification as measured by oxygen absorbed. The wool scouring firm was therefore advised to treat the waste before discharge to the sewer. But large tanks would be required for the bulky sludge produced by treatment with alumina ferric or ferric chloride, and the sludge would have to be disposed of in some way and would not be suitable for grease recovery. But because of the soap shortage the use of synthetic detergents has again come to the fore. The effect is being felt in the sewage plants with the result that more emulsified liquors are being discharged on the filters. The results of experiments on the treatment of mixtures of detergents and sewage with soda ash were erratic. It is difficult to tell whether a precipitation will take place or not. The precipitate when formed was very light and took a long time to settle.

Part 4. Synthetic Detergents—Experiments Carried Out at Huddersfield on Inhibition of Precipitation With Some Notes on Dilution of Surface Active Agents. By H. H. Goldthrope and J. Nixon.

The surface active agents do not form permanent chemical combinations but merely a loosely held physical association. The surface active agents have also an inhibitory influence on certain bacteria. They lower the surface tension and may affect the transfer of oxygen in aerobic processes. They affect the interfacial tension and will bring more substances to the interface of the bacterial cell and water.

A method of detecting the presence of surface active agents is to acidify the sewage to pH 3.0 and shake vigorously. If

frothing occurs surface active agents is present.

A 2 per cent solution of di-ortho tolyl guanadine in 3 per cent acetic acid precipitates the detergents and can be detectedly by the turbidity produced. Many detergents, however, do not give this reaction, but may be detected by the solubilizing action of the oil soluble dye, National Brilliant Oil Blue B.M.A. suspended in water. Soap also gives this reaction but may be eliminated by acidifying the sample and filtering. The test is then applied to the neutralized filtrate.

An experiment on the effect of various concentrations of Teepol X added to sewage on the precipitation with sulfuric acid at a pH of about 3.0 showed that 25 p.p.m. of this detergent reduced the sludge formed by 12 per cent, 50 p.p.m. by 32 per cent, and 200 p.p.m. by 98 per cent. The oxygen absorbed value of the settled liquor increased with increasing concentration of the detergent. The settled sludge dispersed upon the addition of more detergent. Over a range of pH values of 11.5 to 2.5 sewage containing this detergent did not give any satisfactory precipitation. Sewage containing Teepol X treated with 200 p.p.m. of aluminium sulfate at a pH value 4.5 gave optimum precipitation.

The effect of Teepol X on activated sludge was determined and the following indications were obtained: (1) Up to 230 p.p.m., it had little effect on the settling of mixed liquor. (2) Above 250 p.p.m. it caused a slight dispersal of sludge which was not overcome after 24 hours aeration. (3) It lowered the surface tension of the liquid but pretreatment with aluminum sulfate partially restored the lowering of the surface tension. (4) After aeration of activated sludge in the presence of this detergent, some samples had a tendency to rise and float but this effect was irregular.

The addition of 1 per cent Teepol X to sewage reduced the suspended solids by 36 per cent, indicating that these dispersed solids would be carried into trickling filters without giving indication of an increase in suspended solids. Increased loads on the bed would result due to the surface acting agents and also due to sewage solids which are not settled in the primary tank.

Part 5. Methods of Dealing With the New Problem in Sewage Treatment.

Detergents will make sewage much more difficult to treat.

Curtailment of the use of these products under the conditions prevailing in Great Britain is not feasible. Manufacturers using these products should treat their wastes containing such detergents or pay heavy charges for the extra load put on sewage treatment plants.

At the sewage plant a more costly precipitation process would have to be used or the revenue from the recovery of grease may be lost. Large volumes of sludge would be produced adding to the difficulty of their disposal. Extra biological plant may be required and extra difficulty may be encountered in the disposal of secondary sludge.

H. HEUKELEKIAN

Treatment of Milk Washings by Addition of Coagulants, Sedimentation, and Biological Filtration. BY B. A. SOUTHGATE. *Dairy Industries* (Brit.), March, 1948.

The British Water Pollution Research Laboratory has investigated the treatment of wastes from various milk processing plants by anaerobic fermentation, chemical coagulation, biological filtration, and activated sludge processes. The author concludes that the most suitable method by which milk washings of average strength can be treated to yield a final effluent with a 5-day B.O.D. as low as 20 p.p.m. is to employ a biological process under aerobic conditions. Biological filtration is preferred.

In the ordinary filtration process, with one or more percolating filters in series, it was found that the surface became choked by growths of fungi and bacteria. The difficulty was avoided by using the process of "alternating double filtration," in which the settled wastes are consecutively passed through a filter, a humus tank, a second filter, and a second humus tank, the order of the filters being reversed periodically. Plants of this type, where milk washings were diluted with filter effluent to give a mixture with a B.O.D. of about 300 p.p.m., have handled wastes at the rate of 160 gal.

Coagulant (Anhydrous) (p.p.m.)	Volume Sludge 2-Hr. Settling (per cent)	pH Value Supernatant	Biochemical Oxygen Demand	
			(p.p.m.)	Reduction (per cent)
None	—	6.9	300	—
Ferric chloride, 400 Calcium hydroxide, 400	14	7.2	104	65
Ferrous sulphate, 400 Calcium hydroxide, 300	8	7.6	49	84
Calcium hydroxide (to pH 9) Alumino-ferric, 400	3	6.5	60	80

of mixture per cu. yd. of filtering medium per day (0.24 m.g. per acre-foot per day) to yield a final effluent with a B.O.D. of less than 20 p.p.m. Plants are reported to be operating satisfactorily, but no data are given.

It was found possible to reduce the strength of milk wastes by 70 to 80 per cent, measured by the oxygen-absorbed value or the B.O.D. test, with the use of coagulants. Some representative results for dosages giving optimum reductions are listed in the table at top of page.

Descriptions and the results of treatment of two milk waste plants are given. One, a dairy at Hemyock, Devon, collects, refrigerates, and distributes milk throughout the year, and during the spring and summer makes some milk and ice cream powder. Maximum daily waste volume, exclusive of condenser and other cooling waters, was 27,000 gal. Waste is collected in one of two tanks, used alternately, for batch treatment. Hot solutions of alumino-ferric (300 p.p.m. of the solid salt) and soda ash sufficient to raise the pH to approximately 7 are added, stirred mechanically, and the mixture settled overnight. The supernatant is then pumped through a percolating filter 16 ft. deep and containing 47 cu. yd. of 2½- to 3-in. media. The rate of application to the filter during the test was approximately 340 gal. per cu. yd. media per day. (At 72 p.p.m. B.O.D. this equals 132 cu. ft. of media per pound B.O.D.)

The table at bottom of page gives the results of analyses of composite samples taken throughout a working day in April, 1947.

A second test was made at a Shropshire plant which receives, pasteurizes, and distributes milk, and makes some butter. Wastes discharge into one of two parallel settling tanks, each with a 12,000-gal. capacity. Alumino-ferric, only, is added by immersing a block of it in the entrance channel to the tank. Chemically treated wastes stand overnight and the supernatant is then pumped to a circular percolating filter 5 ft. deep and containing 168 cu. yd. of 2- to 4-in. media. On the day of the test alumino-ferric concentration was about 170 p.p.m., and the filter operated at the rate of about 60 gal. per cu. yd. of media per day, or 168 cu. ft. of media per

Sample	pH	Suspended Solids (p.p.m.)	Biochemical Oxygen Demand	
			(p.p.m.)	Reduction (per cent)
Raw waste	7.0	83	286	—
Chemically treated waste	7.1	12	72	75
Filter effluent	7.5	44	14	95

lb. of B.O.D. constituents. Results of analyses of composite samples follow:

Sample	pH	Suspended Solids (p.p.m.)	Biochemical Oxygen Demand	
			(p.p.m.)	Reduction (%)
Raw waste	6.5	347	690	—
Chemically treated waste				
Settled 1 hour	6.3	166	450	35
Settled overnight	6.4	137	320	54
Effluent from filter				
As taken	7.6	5.6	7	99
Settled 1 hour	7.6	—	6	99

At neither plant was there any difficulty due to filter ponding. Sludge from both plants was dried in lagoons without any difficulty.

WILLIAM A. HASFURTHER

A Study of the Effect of Sewage Distribution on High Rate Filter Efficiency. BY W. Q. KEHR AND C. C. RUCHHOFT (Foreword by W. Scott Johnson). A report by the Department of Public Health and Welfare of Missouri and the U. S. Public Health Service. 44 pp., Dec., 1947.

In June, 1941, the state health departments signatory to the Upper Mississippi River Drainage Basin Agreement sponsored a study of high daily rate trickling filter performance. The results of these studies, published in a bulletin entitled "High Daily Rate Trickling Filter Performance," by Graham Walton, March, 1943, indicated that filter distributors based on the Halverson patents, and of rather elaborate design, when used to apply sewage in the form of a "rain-like" spray were very little, if any, more efficient than conventional distributors operating outside of the range covered by the Halverson patents.

Manufacturers of equipment designed to operate under the Halverson patents protested that the plants included in the study were not typical of plants designed and operated in accordance with their recommendations and that some plants were even utilizing equipment not designed to operate in the range covered by the Halverson patents. As a result of these objections, members of the Upper Mississippi River Board of Public Health Engineers agreed to sponsor a further study of the effect of distribution on high rate sewage filter efficiency, with the assistance of the U. S. Public Health Service, in any plant in any of the signatory states. The selection of the plant was to be made by the manufacturers of equipment licensed under the Halverson patents, the one finally selected being located at Neosho, Mo.

"The Neosho municipal sewage treatment plant has two parallel, high rate filters of the 'Aerofilter' type and was designed for a population of 12,000 and a population equivalent of 22,500, the industrial wastes consisting principally of the wastes from a large milk condensery.

"The design of the plant was such that conditions were almost ideal for the type of study undertaken. The arms of one of the Lakeside 'Aerofilter' distributors originally installed at the plant were replaced with four straight arms and the speed adjusted so that instantaneous applied flow rates were outside the range covered by the basic Halverson patents.

"The first period of study extended from March 19 to April 11, 1945, and the second from July 12 to August 8. Twenty 24-hour composite and five 4-hour composite samples were collected and analyzed from each sampling point during the first period and twenty-four 24-hour composite and two 4-hour composite samples during the second period. In addition, grab samples were collected during both periods for analysis for dissolved oxygen, B.O.D. of the digester supernatant, and special determinations.

"There was no significant difference in the efficiency of the two filters in the removal of B.O.D. or suspended solids in the loading ranges studied. The quantity of B.O.D. removed plotted against loadings followed a straight-line trend rather closely. The curve of best fit for the second period had a slightly higher position and less slope than during the first period. This was undoubtedly due to the higher temperatures and heavier loadings encountered during the latter period. Although the applied loadings exceeded 2.5 lb. of B.O.D. per cu. yd. for both filters, there was no indication of a break from the straight-line trend in either case.

"Loadings were generally low during the first period due to a heavy infiltration condition and the necessity for bypassing a portion of the sewage. During the second period the loadings were much heavier and approximated plant design loadings.

"During the last 4 days of the second period, the maximum possible volume of effluent was recirculated to study filter operation under these conditions. Except for slightly higher removals by both filters, no significant changes were apparent.

"A special study was made to determine the effectiveness of the so-called 'raindrop' application of sewage to the filter in increasing the dissolved oxygen content of the applied sewage. Although there appeared to be an increase of 1.0 p.p.m. in the dissolved oxygen content of the sewage applied to the 'Aerofilter' over that applied to the conventional filter, the increase did not carry through the filter, and there was no appreciable difference in the dissolved oxygen content of the two effluents. This was confirmed by the results of several series of grab samples of the effluents from both filters collected during the study.

"There was no significant difference in the nitrification occurring in the two filters. During the first period of study the average nitrate content of both filters exceeded 4.0 p.p.m. During the latter period, when loadings approaching those for which the plant was designed were encountered, the nitrate content of both filters dropped to less than 0.2 p.p.m.

"A careful study was made of the relationship between filter loadings and nitrification. Of the various parameters used, best correlation was obtained between the quantity of B.O.D. removed and the quantity of nitrites and nitrates produced per 100 lb. of B.O.D. removed. Above a critical load, which was slightly different for the two filters, nitrification was negligible. Below the critical load the filter equipped with an 'Aerofilter' distributor gave slightly better nitrification. As nitrification was negligible during the second period, the study was limited largely to data collected during the first period.

"Sewage distribution studies made during this survey did not include momentary rates of application to the filter surface but were limited to a comparative study of the ability of the two distributors to apply the sewage evenly along a given radius. The coefficients of distribution obtained were not materially different for the two distributors and the limited data obtained during the study of these filters do not permit significant interpretation without further study."

S. C. MARTIN

A Note on Consumption of Vegetables Grown on Sewage Irrigated Land. By A. J. ORENSTEIN. *Public Health* (South Africa), Feb., 1948, p. 47.

Article relates the experience of two mine labor communities with consumption of vegetables grown on sewage irrigated lands. At one mine employing 20,000 natives, vegetables were consumed by them from 1936 to 1944, inclusive. The vegetables were grown on land irrigated by settled, but not filtered, sewage. The sewage passed to the land from a simple sedimentation tank with an average detention period of about two hours.

The average vegetable consumption for the 9 years was 2,900,000 lb. a year. During the entire 9-year period there was no unusual prevalence of intestinal diseases and the enteric rate corresponded with that of the rest of the group of mines employing about 90,000 natives.

A second mine grows vegetables on a similarly irrigated area. About 8,000 natives are employed. The amounts of vegetables consumed were:

Nov. 1945 to June 1946—119,300 lb.
July 1946 to June 1947—271,300 lb.
July 1947 to Aug. 1947— 10,000 lb.

During this period there were three cases of enteric fever—one in September 1945, one in December 1945, and one in January 1947. This is better than the previous experience of this mine. There were no other outbreaks of any other intestinal diseases.

At both mines the vegetables are cooked for about 20 min. in a thick stew-like soup, but some carrots, when available, are eaten raw.

S. C. MARTIN

Enumeration, Isolation and Study of Faecal Streptococci from River Water. By C. L. HANNAY AND IRENE L. NORTON. *Proceedings of the Society for Applied Bacteriology* (England), **194**, 1, 39.

The medium used for the enumeration of fecal streptococci was a modification of Hajna and Perry's medium consisting of buffered glucose broth containing azide in a concentration of 1 in 4,000 and peptone in place of tryptone. This modification resulted in tubes in which only partial decolorization of the indicator took place and yet they contained *streptococcus faecalis* and therefore gave an underestimation of the numbers of these organisms in water samples.

Experiments with pure cultures showed that in the presence of azide maximum count was not obtained until 32 hours, while in the absence of azide maximum count was reached in 19 hours. Both 24 and 48 hour cultures containing azide gave a higher maximum count than the medium containing no azide. Biochemical reactions and characteristics of streptococci isolated from the river water were studied.

H. HEUKELEKIAN

The Oxidation of Aromatic Compounds by Fluorescent Pseudomonads. By R. Y. STAMER. *Jour. Bact.*, **55**, 477 (1948).

Benzoate is widely utilized by fluorescent pseudomonads. Substitutions in the benzoic acid group cause marked reduction in biological activity. Other aromatic compounds such as benzaldehyde, benzyl alcohol, phenylactate, and p-hydroxy phenylactate proved to be good substrates for the development of many strains. Aromatic hydrocarbons, benzene, toluene, and xylene were not attacked by any strains. Phthalates were also not attacked.

If a strain of *P. fluorescents* after growths on yeast agar is tested manometrically for oxygen uptake in the presence of aromatic substances that it can use as a substrate, there is invariably a marked lag before oxygen consumption in excess of autorespiration becomes perceptible. Once oxygen consumption is initiated it increases exponentially for some time until it reaches a maximum which is then maintained to the point of substrate exhaustion. On the other hand, a cell grown in a medium where a single aromatic compound is the sole source of carbon and energy, when tested for its ability to oxidize that particular compound, shows an immediate and rapid oxygen uptake. These results show that the attack of aromatic compounds is brought about by adaptive enzymes. Adaptation is a highly specific process and it takes place with two or more aromatic compounds, after growth on one of them, only when these compounds are members of a single reaction chain.

H. HEUKELEKIAN

The Inhibition of Sulfhydryl Enzymes as the Basis of the Bactericidal Action of Chlorine. By W. E. KNOX, P. K. STUMPF, D. E. GREEN, AND V. H. AUERBACH. *Jour. Bact.*, **55**, 451–458 (1948).

The bactericidal effect of chlorine on bacteria had previously been shown to depend upon the inhibition of certain essential enzyme systems such as the sulfhydryl groups.

The work was conducted with suspensions of pure culture of *E. coli*. It was found that bactericidal concentration of chlorine depended upon the number of bacteria. The relationship is expressed on the basis of mg. of Cl per mg. of nitrogen in the *E. coli* suspension. With increasing amounts of chlorine per mg. of bacterial nitrogen the percentage of kill increases. For example, nearly 100 per cent kill is obtained with a dosage of 150 mg. of Cl per mg. of nitrogen.

Such bactericidal amounts of chlorine are far below the amount required to cause cell lysis or nonspecific protein denaturation. Death of the cells parallels the inhibition of glucose oxidation. Sterility of

bacterial suspension occurs only when chlorine has inhibited glucose oxidation fully. It follows that chlorine acts by specifically inhibiting one or more enzymes of glucose oxidation which is essential for the viability of the cell. The possibility that the inhibition of glucose oxidation is a result of cell death rather than a cause is considered unlikely by the authors.

Chlorine inhibits the action of sulfhydryl enzymes, such as papain. This phenomenon has been used for assay of free chlorine in water. Other sulfhydryl enzymes such as zymohesase, triosephosphate dehydrogenase, d-amino acid oxidase, transaminase, and succimic oxidase are also inhibited by chlorine, but catalase, a non-sulfhydryl enzyme, is not affected. Chlorine oxidizes these enzymes irreversibly. The adolase of *E. coli* was shown to be one of the essential enzymes of glucose oxidation, sufficiently sensitive to chlorine to explain its bactericidal effect.

H. HEUKELEKIAN

The Merrimack River Valley Sewerage District Project. By THOMAS R. CAMP. *Journal of the Boston Society of Civil Engineers,* **35**, 2, 115 (April, 1948).

This paper is a condensation of the engineering report which was prepared by Mr. Camp's firm for the Merrimack River Valley Joint Investigation Board. An abstract of Camp's report was carried in THIS JOURNAL, **20**, 4, 591 (May, 1948).

Proceedings of the 29th Texas Water Works and Sewerage Short Course. 206 pp.

This is a complete report of the 1947 Texas Water Works and Sewerage Short Course. The condensed table of contents is as follows:

Program
Registration List
Minutes of Short Course Meeting
Minutes of Business Meeting of Texas Sewage Section
Committee Reports
Lectures on General Topics of Water Supply and Sewage Treatment
Lectures for Grade A, B, and C Water Supply Course

Lectures for the sewage course covered a variety of topics and contained a great deal of information of value to sewage works men, particularly the operators of smaller plants. The majority of the lectures are published in abstract form.

The proceedings also includes a roster of certified water and sewage works operators, and a tabulated census of the sanitary status of Texas municipalities, as of January 1, 1947. The census tabulation includes the 1940 population; the source, ownership, and treatment of municipal water supplies; and the ownership, type of sewer systems and treatment, and outlet streams of municipal sewerage systems.

S. C. MARTIN

New 80,000 g.p.m. Oil-Water Separator Deviates from Conventional Design. By LOGAN ROSS. *Petroleum Processing,* 3, 114–16 (February, 1948).

New oil-water separator facilities capable of handling 80,000 g.p.m. (35,000 g.p.m. process water, 45,000 g.p.m. storm water) and costing over $750,000 have recently been installed at the Toledo refinery of Standard Oil Company (Ohio).

Although designed on the same basic principles of separation by gravity differential used in the standard API oil-water separator, the new Sohio separator differs in some respects from conventional units.

The usual API design calls for a primary chamber and a secondary chamber for each separator section, the primary section including a film rupture tray. In the new installation, however, the film rupture tray is replaced with a straight weir plate, and only 1 section is used for each of the 20 separator sections, with a common influent channel serving all of them.

These single chambers perform the final oil and sludge removal operations, and are equipped with an oil skimming and sludge scraping device in the same manner as the API primary chamber. They are longer, however, than the usual primary chamber; they are about as long as the secondary chamber would be.

The entire installation covers 10.2 acres. In addition to the distribution channel and 20 separator sections, it includes a sludge pond of approximately 3 acres, 2 2100-bbl. storage tanks for recovered oil, pump

house and office, and fire protection system.

One interesting feature of the new facilities is that they are designed to accommodate the waste water of both the Sohio refinery and that of the Pure Oil Co., which has a plant on adjacent property. The waste waters of both refineries are collected in a common culvert which carries them to the separator.

In operation, waste water from the refineries flows from the culvert into the common distribution channel. Here some of the sludge settles to the bottom, and it is periodically pumped to the sludge pond. The waste water then enters as many of the 20 separator sections as are in operation, passes over a weir, and flows the full length of the section. During this period oil rises to the top and sludge settles to the bottom. The oil on top is skimmed off, flows by gravity through an oil collector system to pumps which lift it to the storage tanks. The sludge is scraped into hoppers at the upstream end of each chamber, and pumped to the sludge pond. The clear effluent from each chamber flows into a collector channel and is disposed of without further treatment, passing into a nearby creek which carries it to Lake Erie.

The process design was based on field samples of waste water containing 400 p.p.m. turbidity. The average minimum water temperature was set at 70° F., and the average minimum gravity of the oil in the water at 23° API. The new unit was placed in operation last August and it has been kept under close observation since that time. Numerous laboratory tests of influent and effluent samples indicate that the operation of the separator is entirely satisfactory, and that it is actually reducing the oil and solids content of the waste water to a greater degree than had been anticipated. RICHARD D. HOAK

SEWAGE WORKS EQUIPMENT AND SUPPLIES*

ANACONDA
from mine to consumer

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Conn.

COPPER-SILICON ALLOYS FOR SEWAGE TREATMENT EQUIPMENT

This strong highly corrosion-resistant group of alloys, typified by The American Brass Company's Everdur Metal, has given superior service in the sewage equipment field for nearly two decades.

Everdur, made in several types, consists essentially of copper and silicon, with controlled additions of other elements. The tensile strength, in wrought form, ranges from a minimum of 50,000 p.s.i. for annealed tank plates to approximately 100,000 p.s.i. in cold worked forms. Everdur alloys all possess high fatigue resistance and resistance to corrosion equal to or better than pure copper. There are Everdur alloys adjusted for hot working and for cold work and, with two exceptions, these metals are readily welded by either the oxy-acetylene torch or the carbon arc.

Applications

The principal applications of Everdur for sewage treatment are as follows: coarse and fine screens, swing gates, built-up sluice gates, coarse bar rack aprons, effluent weirs and scum weirs, scum baffles and brackets, troughs, screen hoppers, orifices, baskets, anchors, ladders, float gage chain, valve springs, manhole steps, walk-

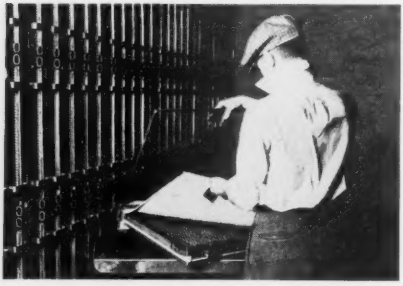

FIGURE 1.—Air filter of secondary room of the Ward's Island sewage treatment plant. Framework of filter structure and filter holders is of welded and bolted Everdur sheet and strip. Retaining mesh for filter is perforated Everdur sheet. Fabricated by American Filter Co., Inc.

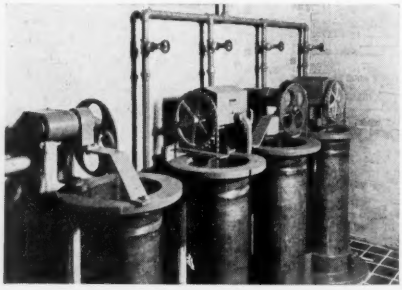

FIGURE 2.—Control mechanism of 12-in. diameter Everdur float tubes. Designed by Krajewski-Pesant Mfg. Corp. for the Ward's Island sewage treatment plant, New York City.

* The material presented here consists of contributions made by advertisers in this issue, and carries no official endorsement. The section is offered as a readership service, affording information on the latest developments in the equipment and supplies finding application in the sewage works field.

ways, bars and plates, bolts and nuts, electrical metallic tubing and rigid conduit.

Advantages

Because of high strength corrosion-resistance and weldability, copper- silicon alloys have effected considerable economies in equipment previously made of heavy iron castings. Relatively lightweight wrought sheets of Everdur, assembled by welding, provide much lighter, more easily operated and more durable equipment.

These copper alloys cost less than most high strength corrosion-resistant alloys and not only meet many of the definitely determined corrosion problems of sewage treatment, but also provide the necessary additional protection where the forces of corrosion are variable.

AMERICAN CAR AND FOUNDRY COMPANY

30 Church St., New York 8, N. Y.

It is becoming standard practice to use lubricated plug type valves in sewage treatment plants instead of the conventional gate valves, especially on sludge line service. This design valve operates from full open to full closed with a quarter (90°) rotary turn of the plug. The cylindrical type of plug valve not only accomplishes full pipe area, thus offering no restriction to the flow of lading, but it also accomplishes a shearing action by means of which any foreign material in the lading is cut and does not interfere with the operation of the valve.

Furthermore, with the ACF Lubricated Plug Valve there are no actual seating elements exposed to the wear of the lading when on flow, and this adds very materially to the life of the valve. There are no pockets in ACF Lubricated Plug Valves for lodgment of foreign material. These valves are offered with gate valve face-to-face di-

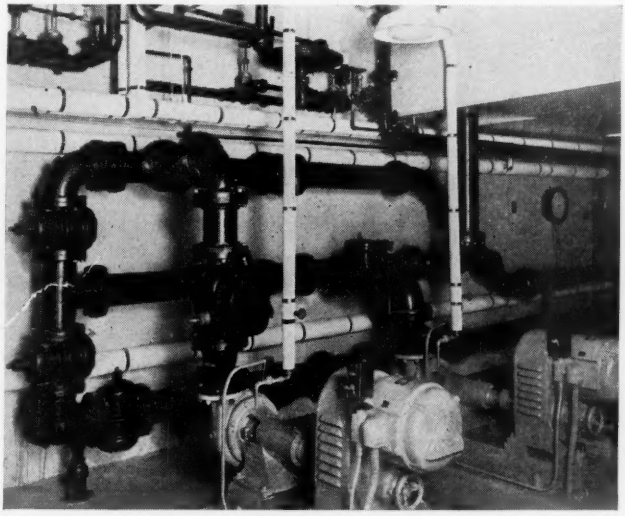

FIGURE 1.—ACF Lubricated Plug Valves in Sludge Pump Room of sewage treatment plant at Peru, Illinois.

mensions and can be arranged for gear operation either with hand-wheels or overhead chain wheels. Smaller sizes are wrench operated. Prices compare favorably with gate valves.

In addition to sludge these valves are used for handling such services as raw sewage, air, by-product gas, caustic, acids, hot and cold water, etc.

Catalog and other literature can be obtained from American Car and Foundry Company, Valve Division, 30 Church Street, New York 8, New York.

THE AMERICAN CONCRETE PIPE ASSOCIATION

288 North LaSalle Street, Chicago, Ill.

The American Concrete Pipe Association is the national authoritative spokesman for the concrete pipe industry, with 150 member companies in the United States, and active members in Canada, Mexico, South America, Great Britain, Sweden, Holland, France, Switzerland, Egypt, South Africa, India, Australia, New Zealand, Czechoslovakia and the Hawaiian Islands.

The objects of the Association are to advance the art and science of concrete pipe manufacture by investigation, research and technical data; to promote and encourage interest between the manufacturers; and to provide a central point of reference for those engaged and interested in the concrete pipe industry.

The affairs of the American Concrete Pipe Association are managed by a Board of Direction representative of the entire industry. This Board meets and has entire charge of management, including assessment of dues, determination of policies, and employment of staff.

The headquarters office in Chicago boasts a library of the most authoritative information on concrete pipe. Activities are concentrated on national advertising, direct promotion and the preparation of authoritative technical literature. One 275-page manual, "Concrete Pipe Lines," has gained wide recognition, and has been requested in great numbers from all states in the Union and from many foreign countries.

The Association is incorporated in Illinois as a not-for-profit corporation. It is financed by the members after a schedule of dues has been determined yearly by the Board of Direction. All income of the Association is spent in the direct interest of the industry. The national advertising is pro-rated among the leading national technical journals. Money is appropriated for research in the engineering field of hydraulics and in the performance of concrete pipe. Direct promotion is carried on in Washington and, as time and money permits, in every state in the Union.

Annually the association holds a convention which is attended by many of the leaders of the industry. The programs of these meetings consist of up-to-the-minute technical presentations, speeches by figures of national prominence in the field of business or general news interest, and social events. These meetings afford an opportunity for every member company to approve or disapprove the action of the Board, and to propose new items for approval or discussion by the entire industry. The industry is small enough for each member company to take an active part in the affairs of its trade association.

Concrete pipe has been in use since the days of the Romans in the year 80.

The industry produces a product which is permanent in every sense of the word. It is so durable that many projects using concrete pipe are being designed with the life expectancy exceeding 100 years. Its main fields of use are irrigation, sewers and drainage, culverts, and pressure water supply lines, in sizes from 4 in. through 15 ft. inside diameter.

HOWARD F. PECKWORTH,
Managing Director

THE AMERICAN WELL WORKS

Aurora, Illinois

JET AERATION

Modern research has produced a great advancement in the operation of the activated sludge process. The AMERICAN Jet Aerator * was developed by the research staff of a large industrial organization for more economical treatment of industrial wastes. American Well Works has continued this development and at present strong phenolic waste, domestic sewage, and milk waste are being treated, using AMERICAN Jet Aerators.

In the past, maintenance of existing equipment received paramount attention, with little thought given to improving the process efficiency. Any device eliminating great maintenance and operation costs of porous plate design and effecting higher operating efficiency is a definite advancement in the science. Such a device is the AMERICAN Jet Aerator.

A large activated sludge plant has now been in successful operation for many months using AMERICAN jets in parallel with their old porous plate installation. The sewage is an average domestic sewage, with the comparative methods of aeration being done in identical tanks each having an effective length of 359 ft. All sewage flows, air flows, and laboratory analyses are measured simultaneously for the two methods.

A graphic representation of typical operating results is shown in Figure 1. Assuming the oxygen absorption with

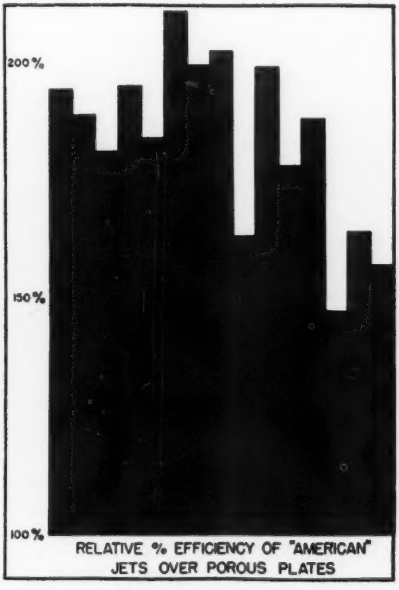

FIGURE 1.—Relative oxygen absorption efficiency of American Jets over porous plates.

porous plates at 100 per cent, the figure illustrates the relative percentage with which the AMERICAN Jets have been operating. Whereas these figures were computed from actual flow and B.O.D. measurements, there also has been direct testing of oxygen absorption.

The data shown in Table 1 provide the percentage absorption at three points of each tank for both AMERI–

* Licensed by The Dow Chemical Company.

TABLE 1.—Direct Oxygen Readings from Actual Operating Results

Date	American Jets Per Cent Absorption			Porous Plates Per Cent Absorption		
	1	2	3	1	2	3
6-25	10.5	—	9.5	5.2	5.2	4.3
6-28	20.5	10.5	8.6	7.6	5.7	4.8
6-29	7.6	9.5	10.0	7.6	4.8	6.7
6-30	10.5	8.1	8.1	7.6	6.6	6.2

CAN Jets and porous plate installations. It can be noted that a maximum of 20.5 per cent oxygen absorption was obtained at one point by the use of Jets, whereas the maximum obtained at a comparable location was 7.6 per cent with porous plates.

During the past year there have been several plants operating, on both a large and small scale, with AMERICAN Jet Aeration. It is proving its many advantages, both in economy of operation and maintenance. Consideration of this method of aeration should be given for new plants and for rehabilitating existing plants. We will be glad to cooperate with consulting and operating engineers in working out specific problems.

ARMCO DRAINAGE & METAL PRODUCTS, INC.

Middletown, Ohio

SALVAGING FAILING SEWERS WITH METAL PIPE

How to save old or failing sewers to avoid complete replacement is a common problem. By relining with a thin-walled corrugated metal pipe, the waterway area is reduced only a minimum, while the old structure is strengthened to carry the load.

The North Shore Sanitary District, Waukegan, Ill., faced the problem of repairing a failed sewer that serves as a by-pass at its North Chicago sewage treatment plant. The sewer, of monolithic concrete, 48-in. diameter, 300 ft. long and built about 1929, carries storm water and wastes from nearby industries.

By 1945 the invert of the monolith was completely destroyed for a width of 15 inches. Sewage flowed under the structure and threatened undermining because of flow at the rate of 15 ft. per second.

Fill over the sewer ranged from 15 to 22 ft., making replacement by the open-cut method costly. The District decided to reline the old structure by threading a smaller pipe inside the original 48-in. line. For this, a 42-in. ARMCO ASBESTOS-BONDED Pipe, bituminous coated and with paved invert, was selected. The pipe was fitted with internal expanding coupling bands to provide watertight joints.

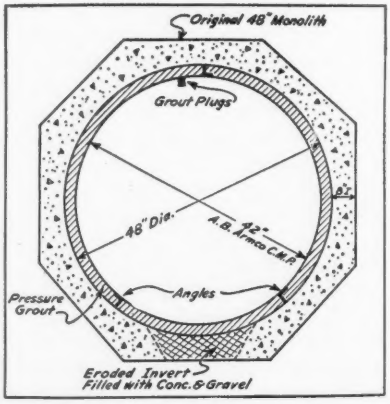

FIGURE 1.—Method of relining old concrete sewer with Armco Asbestos-Bonded Pipe.

Steel angles were welded to the pipe at the one-third points to provide runners for sliding the pipe and keeping it centered in the old structure. Grout was placed in the space between the old and new sewers (Figure 1).

Manholes at each bend in the sewer line were also made of ARMCO ASBESTOS-BONDED Pipe, bituminous coated after fabrication. These were from 16 to 22 ft. deep.

The structure has been in service for two years and has handled the corrosive trade wastes and their strong eroding characteristics without difficulty.

The James Anderson Company of Lake Forest, Illinois, served as the designing engineers. John Darrow of Waukegan, Illinois, was the engineer.

"Sewer Problems—And Answers" is the title of a 25-min. presentation consisting of 92 slides (2 × 2) and a 16-in. record telling how many cities have repaired failing sewers or installed new ones. The presentation is suitable for local engineering meetings and programs, and is available without charge by writing to Armco Drainage and Metal Products, Inc., Middletown, Ohio.

BAILEY METER COMPANY

Cleveland 10, Ohio

BAILEY METERS FOR SEWAGE TREATMENT PLANTS

For measuring sewage flow the Bailey Meter Company offers mechanically or electrically operated recording instruments applicable to flumes, weirs or atmospheric discharge nozzles.

Bailey Direct Mechanical Registers are located at the float tube or still well and are actuated by a float and cable arrangement. The indicating, recording and integrating features of the recorder are driven by direct connection to the float and cable mechanism. A specially designed cam, which corresponds to the flow head characteristics of the flume, weir or other primary element, makes possible the use of a uniformly graduated circular chart.

Bailey Electronic Type Open Channel Meters result in increased flexibility of application. The float and cable operate an electronic transmitter connected to a register which may be placed at any convenient location any distance away from the channel. A standard Bailey Electronic Receiver is used as the indicating, recording and integrating register. This, as well as the direct mechanical register, is suitable for wall, panel or pedestal mounting. It is possible to connect two or more transmitters to the same electronic register to record the total flow through a number of flumes or weirs.

Both types of Bailey Open Channel Meters may be supplied with integrator contacts for the regulation of chemical feed. They may also be supplied with pneumatic control for controlling rate of flow or flow ratio. The electronic meters may be provided with electrical contacts or rheostats for the regulation of pump speeds and other factors through electronic motor control equipment such as General Electric Thymotrols.

It is possible to change the maximum capacity of any Bailey Open Channel Meter without disconnecting the measuring system. This is done by replacing the specially designed cam and the gears which drive it. The only limitation on meter capacity is the basic maximum capacity of the primary element.

Both types of meters are completely described and explained in Bulletin 62, "Bailey Open Channel Meters."

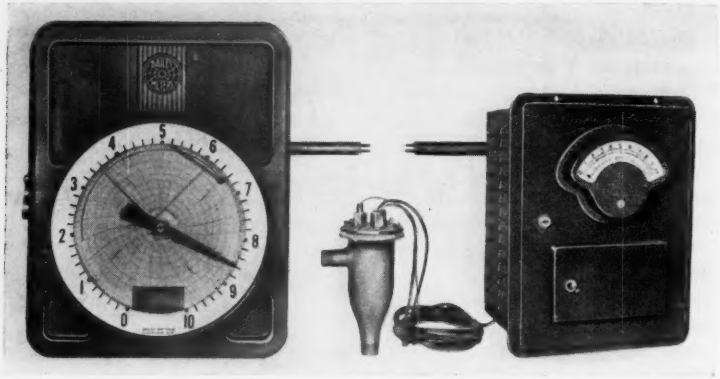

FIGURE 1.—Component parts of the Bailey pH Recorder.

In recent years sewage works operators have become interested in knowing the pH of sewage at various stages of treatment. The Bailey pH Recorder (Figure 1) was developed for this purpose. This instrument is composed of a Beckman pH Electrode Assembly and Amplifier connected to a standard Bailey Electronic Recorder.

The electrometric method of pH determination is used. This system utilizes the difference between one electrode whose voltage is fixed and a second whose voltage varies with pH. Flow or emersion type electrodes may be used.

Two continuous records of pH may be obtained on one chart. It is also possible to combine a pH record with one or two records of flow. Automatic control of the pneumatic or electric type may also be provided. This instrument is completely described and explained in Bulletin 234, "Bailey pH Recorder."

THE BROWN INSTRUMENT COMPANY

DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

4518 Wayne Ave., Philadelphia 44, Pa.

A new 44 page bulletin No. 7301, "Instruments for Treatment of Sewage and Industrial Wastes," is announced by The Brown Instrument Company, Division of Minneapolis-Honeywell Regulator Company. This bulletin is designed to acquaint engineers, superintendents, and operators with the manifold applications of measuring and controlling instruments for sewage and waste processes.

As nearly as can be determined, it is the most complete handbook published on this subject. Included are instrumentation diagrams of a score of applications including flow measurement of sewage, sludge, elutriator wash water, air and gas; temperature measurement of digester sludge and heating water, dryers, incinerators and gas engine cylinder exhausts; pH measurement and automatic control applications; digester level; air conditioning, heating and ventilating controls for administration buildings and laboratories; and boiler room instrumentation.

Several pages are devoted to clear

and concise explanations of the operating principles of the various instruments. This section also includes illustrations, specifications and drilling dimensions of the diversified products needed to adequately meet individual application requirements.

To aid in meeting unprecedented demand to more adequately treat sewage and industrial waste, and recognizing the importance of instruments and controls in this endeavor, information for the purpose of spreading technical knowledge on instrumentation has been prepared in various forms.

Additional recently prepared literature includes Instrumentation Data Sheets Nos. 9.6-1 Ratio Flow Control in Activated Sludge Plants, 9.6-2 Automatic Control of Bar Screen Cleaning, 9.6-3 Flow Measurement in Sewage Plants, and 9.6-4 Instrumentation of Separate Sludge Digesters. Written concisely and illustrated with line drawings and installation photographs, these sheets analyze requirements and present the solution in strictly an engineering fashion.

Each sheet concerns itself with one application only, but is numbered for sequence and punched for convenient loose-leaf notebook filing. Many more Instrumentation Data Sheets on other applications in sewage and waste treatment processing are to be issued.

Inquiries for the bulletin or data sheets, all of which are free, are invited.

To augment the instrumentation information described above, a lecture complete with slides has been prepared on the same subject. Group requests for this illustrated discussion are solicited.

BUILDERS–PROVIDENCE, INC.

Division of Builders Iron Foundry

28 Codding Street, Providence 1, R. I.

Simplified Continuous Weighing Scale for Sludge

For accurate weighing of sewage sludge carried on a conveyor belt, Builders-Providence, Inc., offers the Conveyoflo Meter (Figure 1). This meter uses diaphragms instead of the knife-edge scale-beam principle, eliminating bulky overhead framework. The weighing section, supported at one end by self-aligning ball bearing pillow blocks, "floats" at the other end

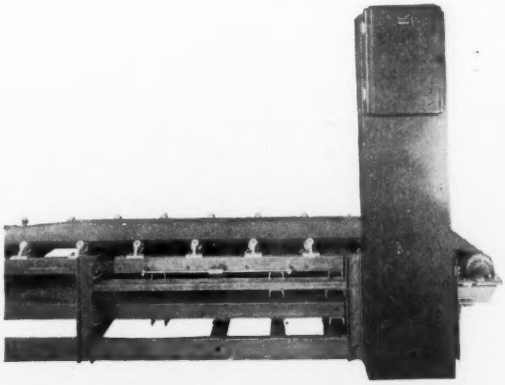

FIGURE 1.—Builders-Providence Conveyoflo Meter.

on a diaphragm that transmits load changes pneumatically to the weighing mechanism. The cyclometer type totalizer (located at scale or elsewhere in plant) reads directly in any unit desired, is non-cyclical in operation, employs the disc and wheel integrating principle, and is automatically corrected for any belt speed variations. Integration is automatically compensated for variations in belt weight and for adherence of material to the belt, through return belt weighing.

Propeller Type Effluent Meter

A low cost, easily maintained and long-service meter for totalizing flow of water and clear effluent is offered in the Propeloflo Meter. The unique Venturi design creates uniform velocity distribution where flow meets propeller, increasing accuracy over an unusually wide range. Loss of head is minimized by streamlining propeller bracket, hub and nose, giving savings in pumping costs. A complete unit in itself, it may be installed in any position, from horizontal to vertical, as easily as a corresponding length of pipe. A clear plastic bonnet protects the totalizer which reads directly in gallons or cubic feet.

Primary Sludge Meter

To insure continuous operation of Venturi Meters handling primary sludge and liquids especially difficult to meter, Builders-Providence offers a simple and ingenious flushing arrangement known as the Flush Check System. Since annular chambers of a standard Venturi tube would require frequent cleaning under such operating conditions, they are omitted and single large vents are substituted at inlet and throat. A small flow of clear water is injected continuously into the Venturi tube through Builders Sightflo Flushing Indicators. Special check valves effectively prevent clogging of vents and small piping.

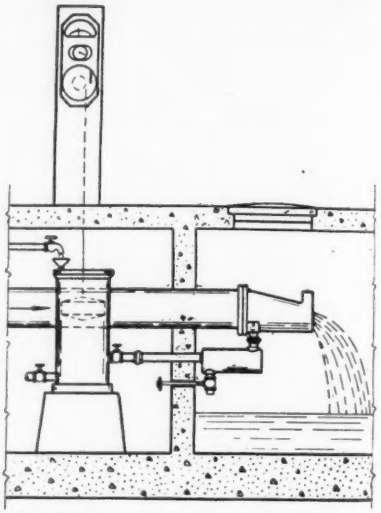

FIGURE 2.—The Kennison Nozzle.

Meter for Open Flow

Small sewage plants metering raw sewage, sludge and trade waste in partially filled pipes and channels will benefit by the accuracy of the Builders-Providence Kennison Nozzle (Figure 2). This consists of an open pipe contracted to a special outlet shape. Solids and debris do not interfere with accurate metering. The nozzle casting is bolted to the pipe through which the sewage flows, with free discharge at shaped end. It has leveling lugs and the top is open for easy inspection or cleaning. At the bottom, near the inlet flange, a relatively large pressure pipe connects through a sediment chamber to the open float well of the recording instrument. (This may be Builders Type M, or Flo-Watch, or for distant transmission—the Chronoflo Telemeter.) Furnished for pipe sizes 6 to 36″.

Outdoor Transmitter Indicator

The Chronoflo Transmitter Indicator in a weatherproof case is offered by Builders-Providence, Inc., for outdoor installation for metering raw sewage effluent using Parshall Flume, weir or

Kennison Nozzle. All operating parts and wiring are fully protected from the weather. Mounted adjacent to an open flow meter, it eliminates need for a separate meter house. The totalizing, recording, receiving instrument may be located in any convenient place in the plant.

CHAIN BELT COMPANY

1606 West Bruce St., Milwaukee 4, Wis.

REX FLOCTROL AND VERTI-FLO COMBINED FOR EFFECTIVE TREATMENT OF INDUSTRIAL WASTE

Being demonstrated daily in the waste treatment plant of a large Eastern manufacturer is the fact that the REX Floctrol and Verti-Flo in combination make a highly successful means of solving that specialized waste treatment problem.

In this particular case, a raw waste of 1250 g.p.m., containing excessive quantities of asbestos fiber, lint, lime, and cement, much of which is light and flocculent and difficult to form into a sturdy floc, needed treatment adequate to permit its disposal into the adjacent waterway.

REX Engineers, working in the laboratory, determined that the waste responded best to a short time, carefully controlled chemical mix followed by a relatively short period of sedimentation in a basin of correct hydraulic characteristics. With this technique the suspended solids load was decreased from 680 p.p.m. to approximately 10 p.p.m. These results are now being duplicated in the full scale installation.

For mixing, a single, three-stage Floctrol, 8 ft. 6 in. wide by 35 ft. long by 8 ft. 6 in. deep, providing a total

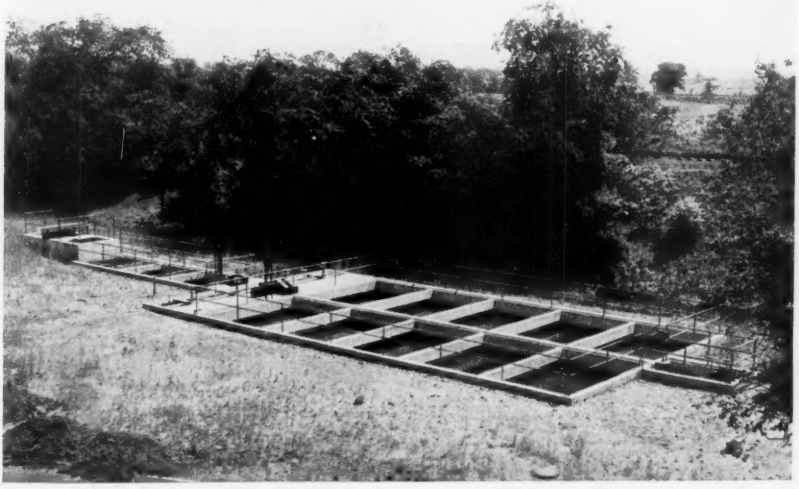

FIGURE 1.—General view of waste treatment plant showing Floctrol and Verti-Flo units.

detention period of 15 minutes, was recommended and installed. Standard Floctrol design was followed, using properly designed paddles, suitably proportioned, rotating baffles, and fixed partition walls with center ports between mixing stages—all arranged to assure thorough mixing and at the same time hold short circuiting through the chamber to a minimum. Areas of center ports in the fixed partitions were selected to provide a head loss between mixing stages of about ¼ inch. This head loss assures the accurate control over flow dispersion which minimizes short circuiting. The rotating baffles serve to diffuse the waste throughout the entire cross section of the chamber, assuring full utilization of tank volume.

From the Floctrol, the floc-bearing waste is carried into duplicate clarifiers, each 16 ft. wide by 64 ft. long by 10 ft. deep, providing a total detention period of 2 hours. This wide departure from the longer, commonly accepted periods of retention in clarifiers in plants of this nature was made possible through the use of the REX Verti-Flo construction. These units have exceptional hydraulic stability, secured by employing a cellular construction obtained by dividing the tank with proper weirs and baffles. The resulting large weir length (8 times that afforded by the conventional tank) keeps vertical velocities low and is the primary reason for the production of an effluent of maximum clarity. All weirs are adjustable to regulate closely the flow distribution among the four cells for highest efficiency.

REX Conveyor Sludge Collectors are employed with the Verti-Flo to concentrate the sludge at the influent ends of the tanks.

These special REX units—the Floctrol and Verti-Flo—will provide an efficient means of handling practically any waste free from domestic sewage or other scum-forming constituents.

CHICAGO PUMP COMPANY

2314 Wolfram St., Chicago 18, Ill.

"PAKAGE" PLANTS, WIDE BAND AERATION WITH SWING DIFFUSERS, COMMINUTORS, AERATED GRIT CHAMBERS, PRECISION DIFFUSER TUBES, SCRU-PELLER PRIMARY SLUDGE PUMPS, FLUSH-KLEEN SEWAGE LIFT STATIONS, RAW SEWAGE PUMPS, PLUNGER SLUDGE PUMPS, WATER SEAL PUMPING UNITS, SAMPLERS

Chicago Pump Company has made many exclusive contributions to sewage and industrial wastes treatment.

Chicago "Pakage" Plants offer an effective low cost complete sewage treatment for populations up to 5,000. They are compact and easily adaptable to varying sewage loads and strengths. Operation is simple; they may be efficiently run by the average small town mechanic. Developed 12 years ago, they are specifically designed to handle the characteristic small community sewage with semi-automatic operation. Nearly 200 Chicago "Package" plants are in successful operation (Figure 1).

Aerated Grit Chambers remove grit particles as small as 0.008 in. without contamination by organic material. Chicago Swing Diffusers located in an aeration type tank set up spiral flows with sufficient velocity to keep organic matter in suspension while the grit is scoured and rolled along the tank bottom to a hopper, where grit is removed by jet pumps.

Chicago Wide Band Air Diffusion System With Swing Diffusers was de-

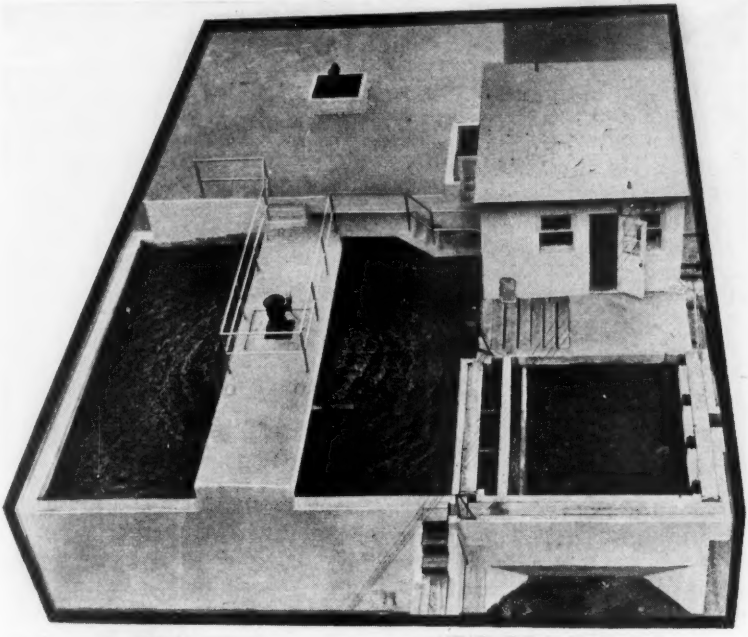

FIGURE 1.—Chicago Pump Company "Pakage" plant at Miami, Fla.

veloped more than 10 years ago to increase the overall efficiency of activated sludge plants. Swing Diffusers can be raised for tube cleaning and for rearrangements of tube spacing to conform with oxygen demand, without dewatering the tank or interrupting operation. The wide band of diffused air provides greater contact between air and mixed liquor and eliminates center coring. Having greater air lift effect, the system develops better tank circulation characteristics. A central orifice, which is an integral part of each diffuser tube, provides uniform air distribution throughout the aeration tank. Operating position of diffuser tubes 2 ft. above the tank floor allows lower blower discharge pressure, or if usual blower pressures are maintained, deeper aeration tanks are possible with resultant savings in first cost. Every major sewage treatment system designed or built since the war has utilized Wide Band Air Diffusion and Chicago Swing Diffusers.

Chicago Precision Diffuser Tubes will withstand more than the usual wear and abrasion. The tube consists of a Saran cord wrapped corrugated stainless steel core, perforated to allow air passage into the corrugations. Air distribution is effected through the tightly twisted filament of the cord providing precise uniformity of fine-bubbled diffusion from the entire active surface without coalescing. The thin wall diffusion media, having one-sixth the thickness of ordinary diffusers, practically eliminates depth clogging and permits quicker and more effective cleaning.

The Chicago Comminutor has been widely accepted among sanitary engineers. When installed in the influent channel, it provides subsurface automatic screening and cutting of sewage solids without removal from the line

of flow. Comminuted particles settle readily with the primary sludge. More than 2,000 are now in operation.

Flush-Kleen Clog-Proof Sewage Pumps have a record of more than 25 years efficient operation in nearly 4,000 units. The Flush-Kleen system is positive and clogproof because an inlet screen keeps sewage solids from entering the pump. The impeller handles only strained sewage. The screen is automatically backwashed and solids are flushed through the discharge pipe.

Chicago Scru-Peller Pumps were developed especially for handling heavy primary sludge. By providing continuous multiple shearing at all times, the screw-feed type impellers cut all solids which would tend to clog ordinary pumps. Specially alloyed shearing edges assure long life and abrasion resistance.

THE CLAY PRODUCTS ASSOCIATION

100 North LaSalle St., Chicago 2, Ill.

NEW SPECIFICATIONS FOR PERFORATED CLAY PIPE

Tentative specifications for perforated vitrified clay pipe have been set up by the American Society for Testing Materials under ASTM Designation C211–47T, issued in 1947. These specifications, which modify the former design of the pipe, are being put into use by members of the Clay Products Association as quickly as possible, and are expected to be adopted as standard. Manufacturers' and dealers' stocks may not conform until present supplies have been exhausted and the changeover completed.

The specifications for perforations are as follows: "Perforations shall be circular and cleanly cut ¼ inch in diameter, arranged in rows parallel to the axis of the pipe. Perforations shall be approximately 3 inches center to center, along rows. The spigot end shall be unperforated for a length equal to the depth of socket. Rows shall be arranged in two equal groups on either side of the vertical center line of the pipe, and the total number of rows shall be as shown in the table. The lowermost rows of perforations in each group shall be separated by an arc of 90 degrees, and the uppermost rows of perforations in each group shall be separated by an arc of 200 degrees. Spacing of rows between these limits shall be uniform."

Other specifications for perforated pipe are identical with those for unperforated pipe, except that there are

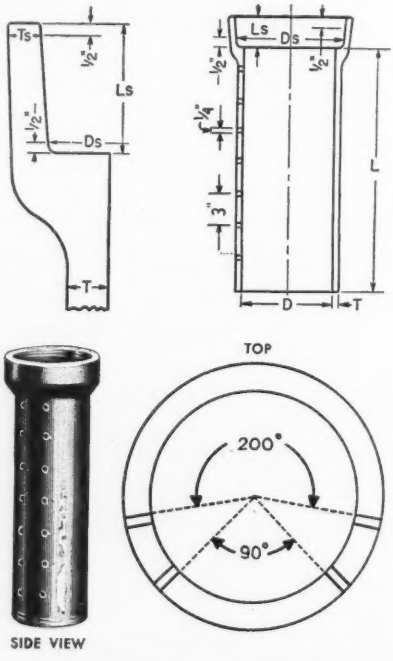

FIGURE 1.—Details of standard perforated clay pipe.

TABLE I.—Dimensions of Standard Strength Perforated Clay Pipe—ASTM Designation C211-47T

Size, in. (*D*)	Laying Length (*L*)		Maximum Difference in Length of Two Opposite Sides, in.	Outside Diameter of Barrel, in.		Inside Diameter of Socket at $\frac{1}{2}$ in. Above Base, in. (D_s)		Rows of Perforations	Perforations per row	Depth of Socket, in. (L_s)		Thickness of Barrel, in. (T)		Thickness of Socket at $\frac{1}{2}$ in. from Outer End, in. (T_s)	
	Nominal, ft.	Limit of Minus Variation,[a] in. per ft. of length		Min.	Max.	Min.	Max.			Nominal	Min.	Nominal	Min.	Nominal	Min.
4	2, 2½, 3	¼	$\frac{5}{16}$	$4\frac{7}{8}$	$5\frac{1}{8}$	$5\frac{3}{4}$	$6\frac{1}{4}$	4	7, 9, 11	$1\frac{3}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{3}{8}$
6	2, 2½, 3	¼	$\frac{3}{8}$	$7\frac{1}{16}$	$7\frac{7}{16}$	$8\frac{1}{16}$	$8\frac{5}{8}$	4	7, 9, 11	$2\frac{1}{4}$	2	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{7}{16}$
8	2, 2½, 3	¼	$\frac{7}{16}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{1}{2}$	11	4	7, 9, 11	$2\frac{1}{4}$	$2\frac{1}{4}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{1}{2}$
10	2, 2½, 3	¼	$\frac{7}{16}$	$11\frac{1}{2}$	12	$12\frac{3}{4}$	$13\frac{1}{4}$	6	7, 9, 11	$2\frac{1}{2}$	$2\frac{1}{2}$	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{9}{16}$
12	2, 2½, 3	¼	$\frac{7}{16}$	$13\frac{3}{4}$	$14\frac{5}{16}$	$15\frac{1}{8}$	$15\frac{3}{4}$	6	7, 9, 11	$2\frac{3}{4}$	$2\frac{1}{2}$	1	$\frac{15}{16}$	$\frac{3}{4}$	$\frac{11}{16}$
15	3, 4	¼	$\frac{1}{2}$	$17\frac{1}{4}$	$17\frac{13}{16}$	$18\frac{5}{8}$	$19\frac{1}{4}$	6	10, 14	$2\frac{7}{8}$	$2\frac{5}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{7}{8}$
18	3, 4	¼	$\frac{1}{2}$	$20\frac{5}{8}$	$21\frac{7}{16}$	$22\frac{1}{4}$	23	8	10, 14	3	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{16}$	$1\frac{1}{16}$
21	3, 4	¼	$\frac{9}{16}$	$24\frac{1}{4}$	25	$25\frac{7}{8}$	$26\frac{3}{4}$	8	10, 14	$3\frac{1}{4}$	3	$1\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{1}{16}$	$1\frac{1}{16}$
24	3, 4	⅜	$\frac{9}{16}$	$27\frac{1}{2}$	$28\frac{1}{2}$	$29\frac{3}{8}$	$30\frac{3}{8}$	8	10, 14	$3\frac{3}{8}$	$3\frac{1}{8}$	2	$1\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$

[a] There is no limit for plus variation.

no requirements on the scoring of the ends of the pipe. Perforated clay pipe, when laid in a porous backfill, provides maximum infiltration and therefore exceptionally rapid drainage. Perforated clay pipe is of great value for subdrainage in very wet soil. Designers are also able to make excellent use of perforated clay pipe in the construction of trickling filters.

THE DORR COMPANY

570 Lexington Ave., New York 22, N. Y.

The year 1948 has found wide spread acceptance of the new Dorr Company developments announced a year ago in the SEWAGE WORKS JOURNAL Convention issue.

Dorr Type-7 Clarifier

The Dorr Type-7 Clarifier for circular tanks, with its rugged design and dependability of operation, has been installed in numerous plants and is giving satisfaction. This unit is an improved design of circular Clarifier mechanisms which The Dorr Company has used for many years and which have demonstrated repeatedly three important factors, namely: (1) economy in first cost, (2) equality in performance to tanks of other shapes, and (3) lowest maintenance cost of any type. There are many examples of Dorr Clarifiers operating for 5 and even 10 years without being dewatered, which should raise the question as to the need for duplicate standby units for use in case of breakdown.

Skimming the Type S-7 Clarifier has been still further perfected and the device employed has demonstrated its ability to remove completely all floating scum from the tank surface at a low moisture content without any assistance from the operator except an occasional pumping out of a skimmings sump.

Duo-Clarifier and Duo-Filter

The combination Duo-Clarifier and Duo-Filter units, employing the Trebler principle, have likewise been received with extreme interest and favor. Several installations in small municipalities have been made and it has also found application in the treatment of wastes from small packing houses. Performance is up to the expected standard. The novelty of obtaining complete two-stage biofiltration in two structures has aroused widespread interest.

Dorrco-Sulzer Disintegrator

The Dorrco-Sulzer Disintegrator is now being installed and operating results are expected within the next few months. As with all new Dorr developments, installations of the disintegrator will be made slowly until the unit has been thoroughly demonstrated under actual plant conditions.

Type M Dorr Digesters

Digesters with high-capacity mixers in a centrally-located draft tube have likewise found widespread acceptance, indicating that operators and engineers who have studied the problem desire adequate mixing for the prevention of scum formation and the maintenance of uniform temperatures throughout the tank. A variety of designs are available, depending upon whether the unit is to be used as a single-stage digester without gas storage; as a single-stage unit with gas storage; or as a primary unit combined with multdigestion.

Coincident with the acceptance of the new type digesters has been the acceptance of the externally-located

Spiral Heat Exchanger. A number of these units have been placed on order during the current year and one of the largest plants of the post-war period has adopted this unit for sludge heating.

THE EIMCO CORPORATION

634-666 South Fourth St., Salt Lake City 8, Utah

EIMCO VACUUM FILTERS

Owing to its physical and chemical properties, sewage sludge yields its water grudgingly, and drainage and evaporation proceed slowly. Therefore, more rapid methods of dewatering are desirable.

Of the methods of dewatering sludge more rapidly than on beds, the one now in most common use is the vacuum filter. In this the water is drawn by suction through a wool or canvas cloth or cord filter medium with openings sufficiently fine so that practically no suspended matter passes through. The general type of vacuum filter consists of a filter drum hung suspended in a vat containing the sludge to be dewatered. Radial partitions divide the filter drum into compartments, each connected by individual pipe lines to a multiple-valve hub so that suction or pressure may be applied automatically and alternately to any compartment as desired.

The surface of the drum is covered with a filter medium through which the water is sucked as the drum revolves through the sludge in the vat, and the solids are left deposited on the surface of the drum in a layer or cake ½ in. or more in thickness. The cake is dried by sucking air through it after it has emerged from the vat. It then is peeled from the drum over a scraper. An agitator in the sludge vat keeps the solids there from stratifying. Eimco uses mechanical agitators, but excess air from blowers has been used satisfactorily in some cases.

A vacuum filter installation consists of a sludge pump or bucket elevator, chemical feeders, sludge conditioning tanks, vacuum filter, vacuum receiving tanks, moisture trap, vacuum pump, filtrate pump, blower, filter cake conveyor and sludge cake hopper. Eimco furnishes all as a complete plant, made entirely in its own works. Eimco recommends the use of acid-proof coatings on the surfaces of all sewage filters and auxiliary equipment, as a protection against corrosion.

To facilitate separation of the solids from the liquid it is necessary to condition the sludge before filtration. This is effected by adding chemicals. In most recent installations the sludge is elutriated before the chemicals are added, thus reducing the amount of chemicals needed, in some cases by 50 to 70 per cent. Conditioning chemicals used are ferric chloride and lime, or ferric chloride alone, depending on the characteristics of the sludge to be dewatered.

The amounts of conditioner used average about 1.5 per cent ferric chloride and 10 per cent lime, on a dry solids basis, for plain settled or chemically precipitated sludge; 1.5 per cent ferric chloride and 8 per cent lime for digested sludge; 1 to 3 per cent ferric chloride for elutriated digested solids, and 3 per cent of ferric chloride only for activated sludge.

The sludge cake removed from the filter can be dropped onto a belt conveyor where it can be weighed and transported to the incinerator or other desired point.

ELECTRO RUST-PROOFING CORP. (N. J.)

Belleville 9, New Jersey

CATHODIC PROTECTION SYSTEMS FOR SUBMERGED METAL STRUCTURES

It has been conservatively estimated that rust and corrosion damage to submerged metal structures costs the public and industry over 6 billion dollars per year.

The effects of corrosion—shortened equipment life, higher upkeep cost and greater out-of-service time—are well known in the sewage treatment field.

Studies have shown that corrosion is electro-chemical in nature and results from the flow of current between areas of differing electrical potential on the submerged or buried surface. These spots act as tiny "batteries" wherein the current flowing through the water (electrolyte) from the anodic to the cathodic areas releases metallic ions which go into solution, resulting in rust and pitting.

To stop this corrosion, Cathodic Protection, by means of auxiliary anodes and an external power supply (or self-energizing anodes), furnishes electrical energy that prevents the flow of current in the local cells on the surface to be protected. Because the current flow is stifled, the escape of metallic ions and the subsequent corrosion is also stopped. In many cases this method has been found especially effective when used in conjunction with paint or other protective coating.

In the field of sewage treatment where corrosion has always been such an important factor, Cathodic Protection has been used on such typical applications as clarifier and flocculator mechanisms (Figure 1).

The effectiveness of Cathodic Protection in these various installations as a method of fighting corrosion is evidenced by the general approval it has received from several widely known organizations. For example, Cathodic

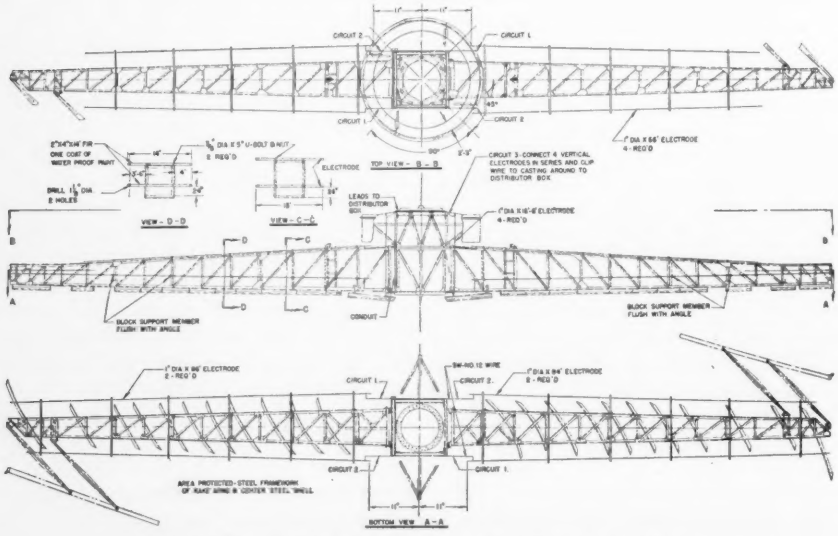
CIRCUIT 2
CIRCUIT 1
CIRCUIT 3 - CONNECT 4 VERTICAL ELECTRODES IN SERIES AND CLIP WIRE TO CASTING AROUND TO DISTRIBUTOR BOX
LEADS TO DISTRIBUTOR BOX
CONDUIT
BLOCK SUPPORT MEMBER FLUSH WITH ANGLE
BOTTOM VIEW A-A

FIGURE 1.—Typical electrode arrangement for clarifier.

Protection is approved by the American Water Works Association, the American Welding Society, and the New England Water Works Association in their publication "Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs, 7H.1–1943," and Electro Rust-Proofing Corp. equipment is approved by the Associated Factory Mutual Fire Insurance Companies.

To furnish a sound efficient system of Cathodic Protection, Electro Rust-Proofing Corporation maintains a complete service for design, manufacture and installation, together with technical representatives in most areas.

For detailed information on Cathodic Protection and how it may be applied in your sewage plant, just write to the Electro Rust-Proofing Corporation, Belleville 9, New Jersey.

FLEXIBLE SEWER-ROD EQUIPMENT CO.

Los Angeles, Calif.

Steady improvements in equipment and methods have increased the speed and efficiency of sewer line maintenance. Before Flexible Steel Sewer Rods were introduced in 1933, men were forced to work in the manholes, which was dangerous, hot, laboriously slow, and expensive work.

Use of quick-connecting steel rods has almost entirely eliminated working below street level and has tripled effective line cleaning distances.

Power Drive

Today most cities use Flexible Steel Rods and Power Drive (Figure 1) for the removal of roots, grease, mud, gravel and sand. Increased work speed, easier handling, greater mobility, heightened safety factors for crews, and elimination of street digups are plus values gained by use of this equipment.

FIGURE 1.—Flexible Power Drive in Operation.

The gasoline-powered drive unit rotates steel rods on the same principle as hand ratchet turning, but at about five times hand-speed. One lever controls all operations. Fully portable, the Flexible Power Drive mounts a specially made Briggs Stratton four cycle engine. The Power Drive can also be used as a universal power take-off and for winch operation.

Ezy Rod Reel

The Ezy Rod Reel and Stand operates as a separate unit, mounted on a tripod or on the new Flexible "Carry-all" trailer. The rods spring out from the reel through a large eye. Very little effort is needed to uncoil and rewind the connected steel rods.

The Ezy Rod Reel and Stand is made of selected materials, which combine lightness with strength. In working position the stand sets at a 45° angle, in perfect balance. It holds over 600 ft. of steel rods without sagging and will not creep as the rods are wound into it.

"Flexichrome" Steel Rods

The development of "Flexichrome" Steel Sewer Rods culminates several years of metallurgic research and extended experimentation. "Flexi-

chrome'' rods provide three to four times the work life of any previous rods. They resist kinking and crystallization, have a hard temper, a high degree of springiness, and a flexible elbow bend at the end of each rod section.

"Flexible" Sand Cups

The Flexible Sand Cup (Figure 2) is unequalled for removing sand blocks from pipes 12 inches in diameter, and smaller. ''Let the water do the work'' is the method employed. When the sand binder is loosened, the lighter sludges, oil and wastes flush ahead of the solids, and the sand is ultimately trapped in the manhole for removal. This method of sand removal is recommended in almost all cases where basements are not endangered by the sewer surcharge and where manholes are at least 4 ft. deep. The rubber cup is collapsible and may be controlled by the actuating rod where roots are encountered.

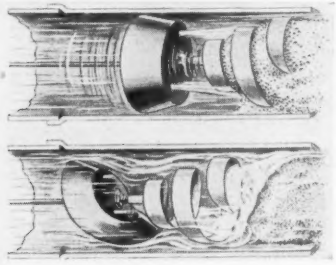

FIGURE 2.—Flexible Sand Cups.

Power Bucket Machine

Flexible Power Bucket Machines (Figure 3) may be towed to the job in tandem, are provided with suitable manhole rollers, and can be set up with extreme rigidity. Extra-heavy buckets with cable swivels to take the twist out of the winding cables make for cleaner sewers and less expensive maintenance. While Flexible will build any type of machine needed by a city, the regular model fills practically all requirements.

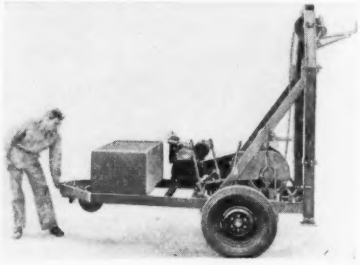

FIGURE 3.—Flexible's Improved Power Bucket Machine.

The level winder used in this equipment is believed to be practically foolproof and a cable saver as well as a great time saver. The 3-belt clutch drive, with booster clutch, is definite insurance against damage of pipe and machine. Collapsible Adjustable Scrapers are used in badly rooted lines, and Hi-Way Culvert Scrapers are used in lines carrying little or no flow.

GENERAL CHEMICAL DIVISION

Allied Chemical & Dye Corporation
New York 6, New York

ALUMINUM SULFATE TREATMENT OF SEWAGE

Stream pollution abatement is being aggressively sought in every section of the country. Municipalities and industries are actively at work on their respective problems and improved stream conditions already have re-

sulted where the answer to these problems has been found and treatment plants built.

Aluminum Sulfate has provided one of the answers, producing a relatively high degree of treatment by the chemical precipitation or coagulation process. The chemical almost universally accepted for clarifying drinking water is enjoying the same acceptance for sewage and industrial waste clarification. This chemical is Aluminum Sulfate.

Aluminum Sulfate as produced commercially has the approximate formula $Al_2(SO_4)_3 \cdot 14\ H_2O$. It is a stable, dry, cream-colored granular or lump material. It is usually packed in 100-lb. multi-walled paper bags. The product dry-feeds nicely and, because of its ready solubility even in cold water, also can be fed in solution form. It dissolves quickly and completely. Entirely eliminated is the clogging of chemical feed lines which frequently causes shutdowns and expensive replacements.

When Aluminum Sulfate is added to sewage a chemical reaction takes place between the "alum" and the alkalinity present in the sewage. Insoluble aluminum hydroxide is formed and this gelatinous precipitate contains the sewage colloids, bacteria and color. On prolonged gentle stirring the precipitate particle increases in size and enmeshes the fine suspended solids in the sewage. The clumping together of the sewage solids results in a large, heavy particle called "floc" by water and sewage works operators.

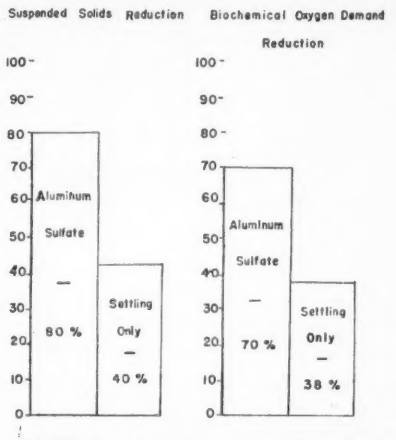

FIGURE 1.—Reductions obtained by coagulation with aluminum sulfate compared with sedimentation only.

After some 30 minutes of "flocculation" the sewage flows to sedimentation units where the heavy floc particles settle to the bottom. The top or supernatant liquor passing to the stream, or to subsequent treating units when necessary, may approach crystal clarity. Since much of the biochemical oxygen demand (B.O.D.) resides in the suspended material, substantial reductions in this demand as well as in suspended solids are obtained (Figure 1).

The engineers of the General Chemical Division will be glad to discuss details of chemical treatment with all operators and engineers operating or designing sewage or waste treatment plants.

GRUENDLER CRUSHER AND PULVERIZER COMPANY

2915–21 N. Market St., St. Louis, Mo.

Sanitary engineers of municipalities have found that Gruendler equipment eliminates the nuisance of undesirable material and waste products clogging sewage and sludge valves and piping. New patented features make possible uninterrupted flow notwithstanding frequent quantities of prevailing rag stock. The Gruendler Shredder is of the swing hammer design with double-

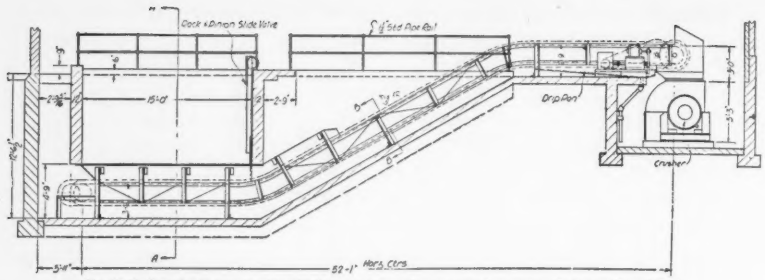

Fig. 371-61—Gruendler Garbage Shredder with Hopper and Apron Conveyor, used in connection with Sewage Disposal Plant.

FIGURE 1.—Diagram showing Gruendler Garbage Shredder with hopper and apron conveyor, used in connection with sewage treatment plant.

end cutting hammers revolving inside a cylindrical shredder plate at 1,200 to 1,800 r.p.m. Capacities are 500 to 8,000 lb. per hour. Motors are direct connected, and range from 5 to 70 h.p.

The Gruendler Shredder is outstanding because of its patented features such as Non Clogging Grate Bars, Safety Tramp Iron Catchers and Improved Water Spray Flushers.

The Gruendler Sewage Screenings Shredder also makes an ideal connection with an incinerator—by grinding, mixing, and preparation in one operation, it prepares product for most efficient combustion and proper feeding.

Gruendler Shredders are dependable and of sturdy construction with sealed bearings to withstand continuous operation. The safety features of the Gruendler Tramp Iron Catcher are noteworthy, since foreign matter such as cans or metal pieces, which is ungrindable, is easily removed through the access door provided. The shredders are built in many sizes and can be fitted in most difficult plant arrangements, taking a minimum of space, and the many designs meet sewage works requirements for higher efficiency. The grinding of sludge to uniform sizes for commercial fertilizer is another operation performed by Gruendler's Hammer-Type Cake Breakers.

Hundreds of Gruendler Shredders have been selected by the U. S. Navy as standard equipment on battleships and merchant vessels.

Blueprints and sewage works layouts, together with specifications, will be gladly furnished municipal engineers, plant superintendents or plant designers by the Gruendler Crusher and Pulverizer Company. Address Plant and General Offices in St. Louis 6, Mo.

HARDINGE COMPANY INCORPORATED

240 Arch St., York, Pennsylvania

Hardinge Center Pier Circular Clarifier

Figure 1 shows the general cross-sectional appearance of the Hardinge Center Column Center Drive Circular Clarifier, which may range in diameter from 60 to 200 feet. This clarifier has proved quite adaptable to sludge collection. The centrally located drive unit is carried on top of the center column, which also supports the rotating mechanism. Sewage enters the tank through a submerged influent pipe which terminates inside the central

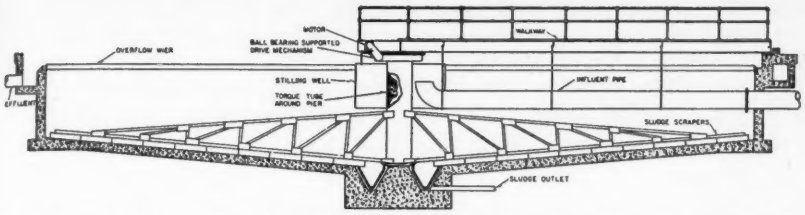

FIGURE 1.—Sectional view of Hardinge type CFCNR Circular, Center-Column Clarifier.

stilling well. Clarified sewage overflows a peripheral weir into a peripheral collecting trough, while settled solids are collected by the rotating scrapers and moved to the center sludge well.

The drive is enclosed and oil lubricated. The bearing which supports the rotating scrapers is a specially designed ring type ball thrust bearing, located beneath the rim of the main drive gear.

A bridge from the side of the tank to the center pier provides access to the center driving gear and motor. The influent pipe is carried by bridge hangers, as shown.

Hardinge Reciprocating Rectangular Clarifier

Although this type of skimmer-scraper has been in use in sewage plants for some time, the installation at the Toledo refinery of Standard Oil Company of Ohio, shown in cross section, Figure 2, is the first installation in which it has been applied to refinery oil-water separation. This installation includes 11 units to handle 40,000 g.p.m. Oil is skimmed off the water surface as the skimming mechanism travels toward the effluent end of the unit, and sludge is scraped from the bottom of the chamber to collecting hoppers near the influent end on the return travel of the skimmer mechanism.

The mechanism reverses mechanically at the end of the skimming operation, after pushing the oil over the skimming apron into the trough. Both sludge and skimmer scrapers alternately raise and lower themselves, operating during one direction of travel only. The unit is designed for continuous operation, although it may be operated intermittently. Electric current to drive the equipment is delivered through an automatic take-up reel located on the moving carriage.

Other Hardinge Sanitation Equipment

Hardinge also offers their type "XH" Rotary Dryer, particularly designed for the dehydration of sewage sludge, after vacuum filters. It is applicable to drying of either activated or digested sludge.

An extremely recent development by the Hardinge Company is the Automatic Backwash Rapid Sand Filter,

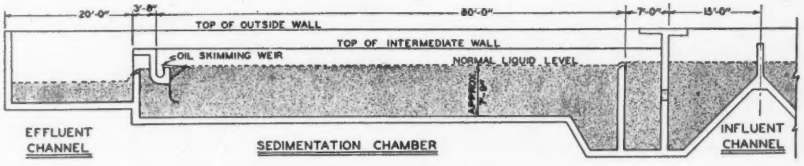

FIGURE 2.—Sectional view through one side of the new oil-water separator, showing the influent channel, sedimentation chamber and effluent channel. Not shown are the oil skimming and sludge scrapping unit and the rails on which it rides.

which may be used to advantage where extremely high removal of suspended matter from final settling tank effluent is required, following trickling filter and activated sludge treatment.

The Hardinge Digester for sewage sludges includes rotating sludge scrapers, scum breaker arms, heating coils, and a gas dome to provide uniform gas production.

INERTOL CO., INC.

480–490 Frelinghuysen Ave., Newark 5, N. J.

INERTOL PAINTS FOR SEWAGE WORKS

In 1927 the Atlantic City Sewage Company applied two coats of Inertol Standard to the interior of a concrete box sewer. At about the same time several coats of a commercial asphalt paint were applied to the interior of a concrete conduit carrying the same sewage.

Six years later the roof of the asphalt-coated conduit collapsed, because the strong hydrogen sulfide fumes had destroyed the asphalt paint and disintegrated the concrete above the sewage level. But the Inertol on the concrete box sewer withstood the action of the gas and gave the concrete full protection. On the ninth annual check-up the engineer found the Inertol Standard to be intact and the concrete to show no sign of corrosion.

A recent inspection shows that the Inertol-painted structure is still "free from any disintegration due to the severe hydrogen sulfide concentration."

Inertol Standard is a superior heavy coal-tar coating designed for use on all steel and concrete work submerged in sewage. Heat is not required to apply Inertol Standard. Its toughness resists mechanical abrasion; its thick-

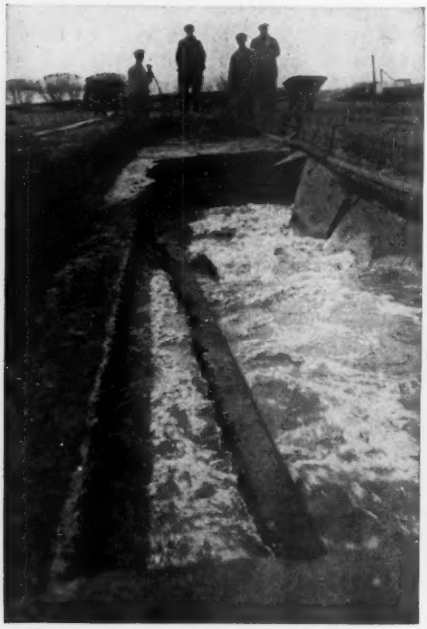

FIGURE 1.—The Atlantic City sewer that asphalt paint failed to protect against hydrogen sulfide.

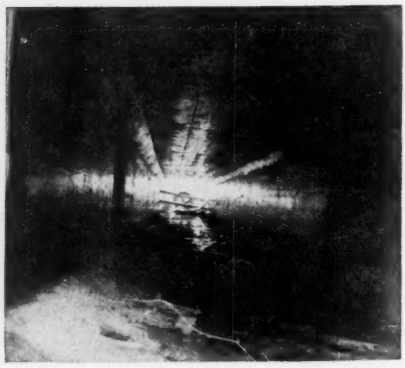

FIGURE 2.—The Atlantic City sewer that Inertol Standard has protected for twenty years.

ness protects the surface from chemical corrosion in sewage. Applied by brush, a coverage on metal of 150 sq. ft. per gal. is obtainable.

Hundreds of sewage treatment plants have used Inertol products with complete satisfaction. Full information concerning the use of Inertol paints can be obtained by writing the Inertol Company, Inc.

INFILCO INC.

325 W. 25th Place, Chicago 16, Ill.

ACCELO-FILTERS, ACCELO BIOX PROCESS, ACTIVATORS, CLARIFIERS, SKIMMERS, ROTARY DISTRIBUTORS, AUTOMATIC DOSING SIPHONS, AUTOMATIC PROPORTIONERS, ACCELATORS, CHEMICAL FEEDERS, CYCLATOR, MIXERS, GRIDUCTORS, COAGULATORS, CONTROLLERS, VORTEX GRIT REMOVERS AND SAMPLERS

Daytona Beach Process

As a result of previous experience in the treatment of certain industrial wastes, pilot plant studies at Daytona Beach have demonstrated the absorptive-coagulating value of calcium carbonate slurry with a small quantity of alum, maintained at a high concentration in an "Accelator," for the treatment of normal domestic sewage. B.O.D. reductions of the order of 80 per cent were obtained in the Accelator. Based on results of these tests, a 12-m.g.d. plant has been designed and is now under construction.

Industrial Waste Treatment

The "Cyclator" (Figure 1) is a development for chemical treatment of industrial wastes. It provides for recycling partially thickened previously precipitated solids for mixture with raw wastes through mixing and reaction zones, and removal of settled solids by means of rotating scraper blades, treated liquor being withdrawn from a launder. If required, an automatic hydraulic skimmer can be provided with the Cyclator mechanism.

A Cyclator and a WS clarifier mechanism, each equipped with a hydraulic skimmer, are being successfully used for acid neutralization and removal of soluble oils and chromates at the Sandusky, Ohio, plant of the New Departure Division of General Motors Corporation. Soluble oil removal in excess of 99 per cent is being obtained.

Another Cyclator installation at the River Raisin Paper Co., at Monroe, Mich., has provided up to 98 per cent suspended solids and 50 per cent

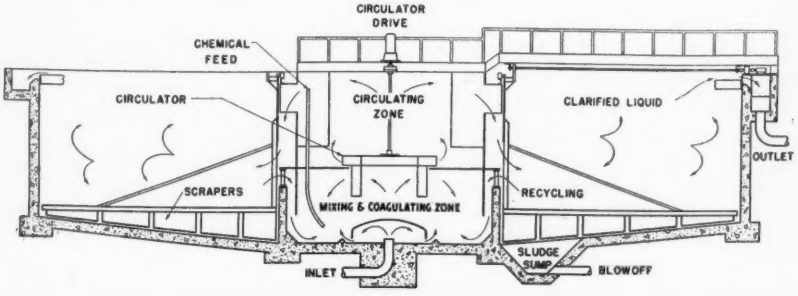

FIGURE 1.—The INFILCO Cyclator.

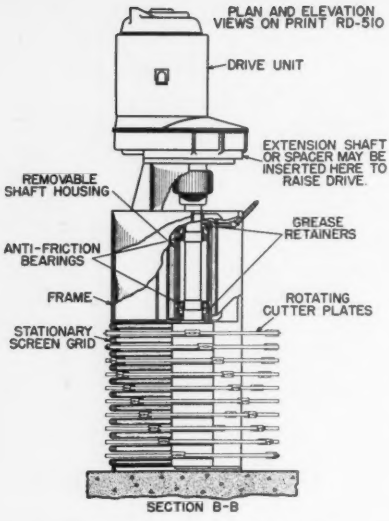

FIGURE 2.—The INFILCO Griductor.

B.O.D. reductions in the treatment of white water from a board machine.

Digester Heating

Development work on a new digester heating device involving direct transfer of heat is progressing satisfactorily, and is expected to be ready for the market late this year or early in 1949.

Improved Griductor

Development of several mechanical improvements has added to the benefits and advantages of the "Griductor" mechanism (Figure 2). The increasing number of successful installations bear witness to the excellence of design and fabrication of this equipment, as well as its simplicity of installation and operation.

JEFFREY MANUFACTURING COMPANY

Columbus 16, Ohio

New Improved Jeffrey V-Bucket Grit Collectors and Grit Washers

Really satisfactory and efficient grit washing is now possible in any size community by using the Jeffrey system of grit collection and washing. The layout in Figure 1 is recommended for small or moderate size cities.

While partial grit washing is possible in the channel by control of velocities, means provided for stirring grit, etc., our field studies covering small and large cities show that for most satisfactory results the grit should be collected by one mechanism and washed in a separate unit. The layout in Figure 1 accomplishes just that, and by providing controls so that each device operates a minimum of time each day, the life of the collector and washer will be prolonged for many years, with a minimum of maintenance.

The grit channel is designed to remove all of the grit above a certain minimum size during conditions of maximum flow through the channel, realizing that with the usual velocity control devices provided at the effluent end of the channel, considerable organic matter will settle out during periods of low flow. This is not objectionable if an efficient washer is provided which will remove these later from the raw grit. It is easily accomplished by passing the raw grit through a Jeffrey Jigrit washer, the efficiency of which has been well demonstrated in small and large cities in the United States.

The improved Jeffrey No. 1 Jigrit Washer has a capacity of 20 cu. ft. per hour. It will effect an 85 per cent removal of organics, leaving almost no organic seeds and light gravity material in the washed product, and will yield 90 per cent recovery of inorganic grit, which can be used for fill or

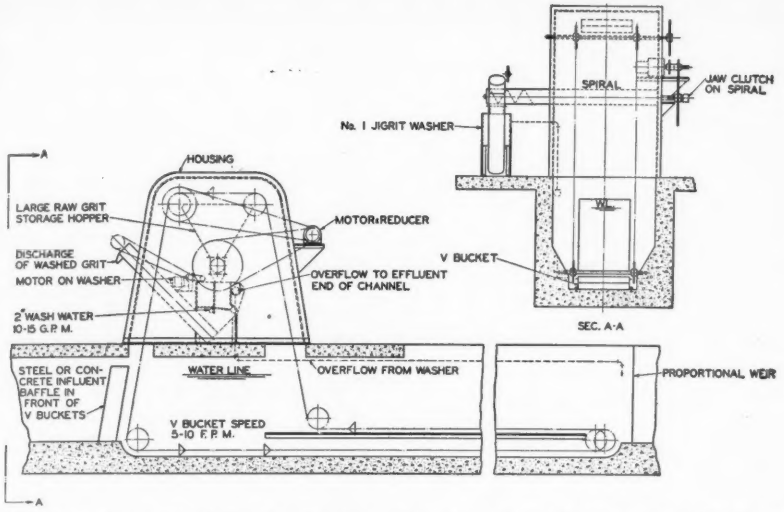

FIGURE 1.—Recommended grit collection and washing layout for sewage works of small or moderate size.

dumped anywhere without nuisance. The latest design eliminates the rubber diaphragm and many working parts, giving longer life at minimum maintenance expense.

In the layout the grit collector and washer run intermittently, with the collector running a few minutes out of each hour and the washer once or twice a day for short periods of time. Normally the grit collector is operated by time control so that it operates intermittently to keep the channel free of grit. The raw grit is discharged into a storage hopper built in the superstructure at the inlet end of the channel. The bottom of this hopper is provided with a spiral conveyor which provides a constant and uniform feed to the washer whenever it is started. The spiral and washer must operate together, although the spiral can be provided with an emergency outlet if desired.

JOHNS-MANVILLE

22 East 40th St., New York 16, N. Y.

TRANSITE SEWER PIPE

Transite Sewer Pipe cuts costs all along the line. It reduces the initial expense of installation and, of even greater importance, it assures long term economies. These savings come from inherent characteristics plus manufacturing improvements.

The pipe ingredients—asbestos, cement and silica—make it unusually resistant to corrosion. This resistance is further increased by special Johns-Manville methods of manufacture.

All Transite Sewer Pipe is steam cured. During this process the free lime ordinarily present in cement products combines with the silica to produce highly stable monosilicates. This stability applies inside, outside, and all the way through the wall structure giving the pipe its characteristic

resistance to corrosion from both sewage and soil.

High Flow Capacity

Transite Sewer Pipe is formed on a polished steel mandrel to produce a uniform and extremely smooth interior with a friction coefficient of $n = 0.010$ (Kutter's formula). As a result of this carrying capacity the designer often may use flatter grades. This means a shallower trench, with less time and money spent on excavation. In any locality this is a real saving, but in locations where rock or stone are encountered it is even more important. As an alternate economy, smaller diameter pipe may be specified.

Reduced Installation Costs

Long length and light weight account for still other economies. Transite Sewer Pipe is made in sections 13 ft. long. This reduces the number of joints to be made and speeds installation. It also facilitates laying the pipe to accurate grade and eliminates many other problems encountered with shorter length sewer pipe. Lightness of weight still further expedites laying and decreases handling charges. More footage per truck can be carried, and the use of expensive mechanical equipment is minimized.

Concrete cradling can often be eliminated because this pipe is available in four strength classes. It comes 4 to 36 in. in diameter in Class 1, 10 to 36 in. in Classes 2 and 3, and 18 in. in Class 4. With this range the designer can specify pipe that yields both efficiency and economy.

Reduced Treatment Costs

Where sewage treatment is practiced, additional money savings show up at the plant after the Transite Sewer Pipe is laid because infiltration of ground water is minimized. In many sewer systems the flow is 25 per cent ground water. The cost of treating infiltration water is practically the same as for treating sewage. Infiltration results in unnecessarily high plant installation and operating costs, in addition to the installation of costly over-size sewers.

With Transite Sewer Pipe infiltration is controlled by two features. One is the long pipe section which reduces the number of joints at which infiltration might occur. The other is the tight sleeve joint which stays tight in service.

Transite Pressure Pipe for Force Mains

Transite Pressure Pipe for force mains assures similar economies. It has a high flow capacity of $C = 140$. Its immunity to tuberculation helps keep pumping costs low. Its resistance to corrosion assures long life. Its easily assembled Simplex Couplings provide tight, flexible joints, each capable of a 5° deflection.

Transite Pressure Pipe is available in sizes 3 in. through 36 in. in classes 100, 150, and 200, for maximum recommended working pressures of 100, 150 and 200 p.s.i., respectively.

For further detailed information on either Transite Sewer Pipe or Transite Pressure Pipe write for explanatory brochures.

LAKESIDE ENGINEERING CORPORATION

222 W. Adams St., Chicago 6, Ill.

The Lakeside Engineering Corporation offers the following items for sewage treatment: round clarifiers, trickling filter distributors, and Trebler Samplers.

Clarifiers

Over 15 years ago the forerunners of the modern Spiraflo clarifier were installed in a new mechanically aerated activated sludge plant at Flora, Ill. Because of a patent (under which Lakeside was unable to secure a license) covering the general idea of scraping sludge to a common point in the clarifier and pumping the sludge to the digester, the Spiraflo was withdrawn from the market. During the war this patent expired and the Spiraflo was again offered to the public. There are now a number of these clarifiers in operation, under construction, or under contract.

Unlike other round clarifiers, the incoming liquid enters a race formed by a skirt suspended from the top of, and adjacent to, the clarifier wall and leaves the clarifier from a centrally located collecting trough (see advertisement in this issue).

Before the liquid can enter the collecting trough it must first pass downward beneath the skirt and then rise in the inner section of the tank. The incoming flow is introduced at the water level, in a tangential fashion, which causes the liquid to rotate around the race, usually in a clockwise manner. This rotation within the race causes the entire liquid content of the tank to rotate slowly and thus minimizes the effect of possible short circuiting under the skirt and upward through the center section of the clarifier. The rotation also helps to carry the lighter solids to the bottom center part of the tank, as can be demonstrated by stirring a glass of water into which light weight settleable solids have been placed.

The race formed between the aluminum skirt and the wall of the tank provides excellent skimming, including the removal of floating grease and oil. In some cases aeration tubes have been placed in the race.

Filter Distributors

The Lakeside trickling filter distributor is available for conventional as well as high capacity filters. When used with high capacity filters the number of arms is increased over what would be required for the same area of a conventional filter. All of these distributors are equipped with centrifugal nozzles connected to the arms in a manner which provides easy field adjustment of the distribution. By actual test these nozzles have discharged as many as five matches at a time. The throats of the nozzles and the connections to the arms are 1¼ in. in diameter, while the orifices in the removable covers of the nozzles are usually ⅞ in. in diameter, or larger. These nozzles are so designed that the orifice does not flow full, but only a ring around the edge of the orifice is used. This arrangement provides good aeration as well as a large opening for discharging solids without at the same time producing a flooding action by the nozzles.

Sewage Samplers

The Trebler Sampler is manufactured by Lakeside Engineering Corporation. The scoops used with these samplers are so designed that the volume of liquid picked up in each revolution of the scoop is in direct ratio to the volume of liquid passing over the weir. Scoops are available for use

with 90° V-notched weirs or with straight weirs. Since the scoops sample in proportion to the flow, they can also be used as a means for calculating the total volume of liquid passing over the weir during a sampling period. The machines are available with or without time clock devices.

Additional information regarding Lakeside products may be obtained by addressing an inquiry direct to the home office at 222 West Adams Street, Chicago 6, Ill.

MABBS HYDRAULIC PACKING COMPANY

431 South Dearborn St., Chicago 5, Ill.

MOST EFFICIENT PACKING FOR SLUDGE AND SEWAGE PUMPS

No equal to rawhide has ever been found in the long history of developing packing for sewage and sludge pumps. This is the almost unanimous decision of sewage plant operators. It is further supported by over 40 years of packing experience on the U. S. Government's hydraulic dredges and by over 50 years of water works experience.

Rawhide packing does not dry out or become glazed. It prevents scoring and wearing of shafts, sleeves, rods, plungers, and valve stems. It is most easily installed. It is most economical, outlasts any other packing and when it is used the dirtiest water can be pumped without injury to shafts, plungers, or rods.

Water provides the lubrication rawhide packing requires. No other lubrication need ever be added. When wet, rawhide is as slippery as an eel and free from friction. As long as rawhide remains wet it will never harden in service. In one case where Mabbs Hydraulic Packing had been used, the stuffing boxes had not been entirely cleaned for 14 years, yet not a mark of grit was found on the equipment.

Mabbs, with its 56 years of experience, has long been the standard name in rawhide packings. The Mabbs Hydraulic Packing Company has developed all the possible superiorities of rawhide and has pointed out and made usable all its inherent values.

Mabbs Rawhide Packings are made from only the most carefully selected top quality rawhides. These hides are thoroughly cured by a special process so that they retain their natural oils during long periods of service. Thus, an always soft, always pliable and durable leather base is provided. Abrasives in the material pumped have no foothold. They are either washed away from the contact surface into the body of the packing, or out of the stuffing box.

Equipment packed with Mabbs Rawhide Packing operates freely and requires little attention. The life of rods and valve stems is prolonged. Replacement expense and time are saved. Shutdowns because of packing trouble are eliminated.

Records of the use of Mabbs pack-

ing are most convincing. "Have used your rawhide packings on our Allis-Chalmers 3,000,000 gallon pump for 20 years—splendid results." "Leakage minimized, packing glands tighter, piston rod moves freely." "Have used your rawhide packing on our hydraulic valves for 15 years—wonderful service—wouldn't change." "Our pump old and worn—no packing other than rawhide would hold—we recommend it to anyone with old pumps and worn stems." "Best packing I ever used—pump runs more easily—don't have to tighten stuffing box so much." (Names on request.)

Mabbs packings are furnished in any size from 1/16 to 2 in., by 1/16-in. increments to 3/4 in., and by 1/8-in. increments in the larger sizes. Mabbs Packing weighs only 2.3 as much as flax. It is packed in standard containers of 5, 10, 25, and 50 lb., in kegs of 100 lb., and in barrels of 200 pounds.

Packing users are invited to send for a liberal free sample of Mabbs Rawhide Packing, in any size, and to subject it to the severest test conditions.

NORDSTROM VALVE DIVISION

Rockwell Manufacturing Company
Pittsburgh, Pa.

NORDSTROM LUBRICATED PLUG VALVES

Nordstrom valves are of the tapered plug cock type, pressure lubricated both for operating ease and to seal against leakage. They are particularly suited for use in sewage treatment plants due to their non-sticking, positive shut-off construction, and are made in sizes from 3/4 in. to 30 in. and for all pressure and temperature requirements. Nordstrom valves quickly open or close by a quarter-turn of the plug and may be operated by wrench, gear or power drive.

Lubricant System in Nordstrom Valves

In the phantom view, Figure 1, the lubricant grooves in the Nordstrom valve plug and body may be clearly seen. These grooves form an interconnecting system which conducts the lubricant from the valve shank to the lower end of the plug in either open or closed position. By simply turning the lubricant screw at the top of the valve, both seat and plug surfaces are completely covered with a film of lubricant. This "Sealdport" method of valve lubrication forces "Nordcoseal" lubricant under high pressure between plug and body and frees the plug to assure easy operation.

Lubricant grooves in the valve body and plug are so arranged that the lubricant cannot be blown from the valve by the fluid or pressure in the line. The Nordstrom method of "Sealdport" lubrication has made practical the use of plug cocks as large as 30 inches in size and assures the most satisfactory service on sludge, gas, water and chemical lines in sewage treatment plants.

Figure 2 shows the plug assembled within the valve body and with the especially designed gland and yoke in place. Even if lubrication is neglected, this valve will remain tightly seated since all unbalanced pressure is in a downward direction. To release the plug after long inoperative periods it is only necessary to turn down the

FIGURE 1.—Phantom view showing Nordstrom "Sealdport" lubrication system.

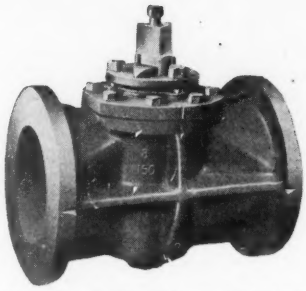

FIGURE 2.—Nordstrom Lubricated Valve.

lubricant screw and lubricant force will free the plug for easy turning.

Standard Dimensions

Nordstrom valves are made in several patterns. One type that has standard gate valve face-to-face dimensions, embodies in its construction all the advantages inherent to the entire line plus the added advantage of interchangeability without remaking companion flange connections.

PACIFIC FLUSH TANK COMPANY

4241 Ravenswood Ave., Chicago 13, Ill.

P.F.T.-KRAUS PROCESS FOR ACTIVATED SLUDGE

The Pacific Flush Tank Company, considering the Kraus Process as developed by L. S. Kraus, Chemist of the Greater Peoria (Ill.) Sanitary and Sewage Disposal District, as a major advance in activated sludge treatment, has taken over promotion and licensing of this process for new and existing installations.

This process has been thoroughly proved in successful operation for several years at Peoria in handling domestic sewage from a population of 115,000, together with industrial wastes of equal or greater population equivalent. It affords a practical and simple means of controlling bulking of activated sludge.

The system is known as the "Digester Liquor Nitrification Process," wherein digester liquor or digested sludge is added to activated sludge in a portion of the aeration tanks termed "nitrifying aeration tanks." The digested sludge is rapidly converted to activated sludge, and the activated sludge so produced is added to the return sludge to the normal aeration tanks (Figure 1).

Since digested sludge contains solids of higher density and greater settleability than activated sludge, the sludge index of the mixture is reduced in proportion to the weighted average of the sludge indices of the two sludges. When the mixed sludges are aerated the digested sludge is converted to activated sludge and the ammonia normally present in digested sludge is oxidized to nitrate and nitrite nitrogen. In addition, some of the organic solids are oxidized. Thus, in the nitrifying aeration tanks a highly oxidizing condition is continuously prevalent, and an activated sludge of low index, high in nitrate, is produced.

The highly oxidizing sludge of low index is then mixed with the normal return activated sludge of higher index. This lowers the index of the return activated sludge and adds nitrate nitrogen to the mixed liquor. The nitrate nitrogen affords an oxygen reserve in the influent zone of the aeration tanks, where the oxygen demand is greatest.

Thus, the method of maintenance of relatively constant sludge index levels consists of balancing the rising index of the return activated sludge in the aeration tanks with the decreasing index in the nitrifying aeration tanks. The amount of correction required is determined by the operator to fit the

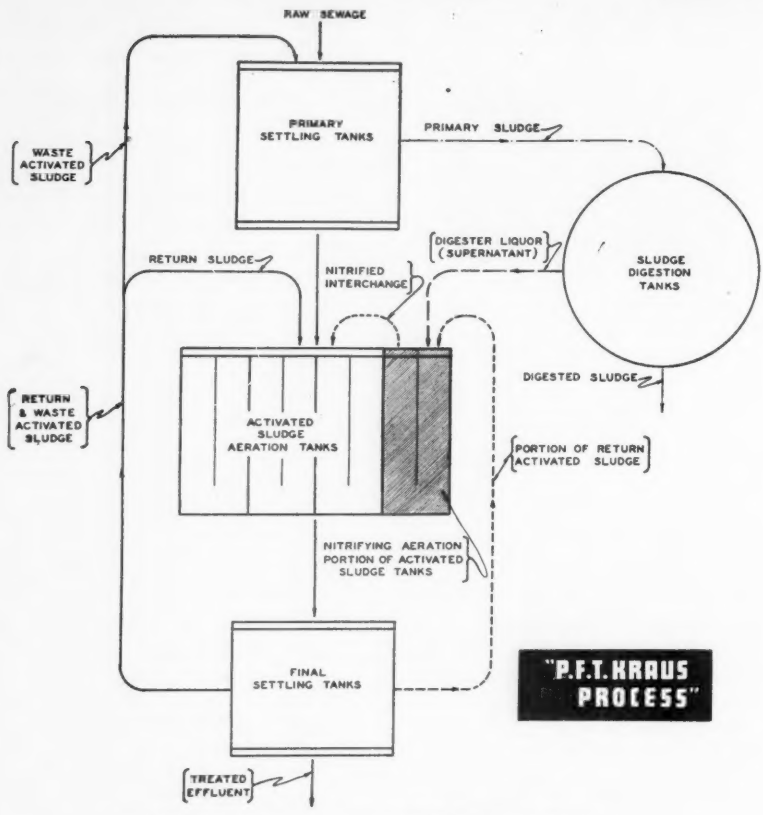

FIGURE 1.—Flow diagram of P.F.T.-Kraus Process.

particular situation in each plant. The digester liquor added to the activated sludge in the nitrifying aeration tank not only provides the denser solids to lower the sludge index but also affords large quantities of ammonia nitrogen, which tends to correct the carbon-nitrogen ratio in the food supply to the activated sludge microorganisms.

There are other beneficial features of the process, as follows:

1. Higher mixed liquor solids can be carried than in normal operation, giving greater stability of sludge index.
2. Shock loads are handled effectively and without process interference.
3. The ever-present digester liquor disposal problem is solved by the use of this material instead of discharge to sewer flow, eliminating the detrimental effects on primary and secondary treatment that are inherent to the latter procedure.

The digester liquor nitrification process does not require any additional aeration basins, aeration facilities or any greater amount of air. It merely calls for a slight revision in normal piping and return activated sludge pumping facilities.

The Pacific Flush Tank Company is prepared to give recommendations to interested plant operators or designers on the application of this process to existing or new treatment plants.

PITTSBURGH EQUITABLE METER DIVISION

A Division of Rockwell Manufacturing Company
Pittsburgh 8, Pa.

Pittsburgh-Empire Water Meters

These meters have, for many years, been used by large and small municipalities alike to account for water consumed in homes and industry. Their excellent construction, maintained accuracy and long life have been thoroughly proven on hundreds of thousands of installations.

In sewage treatment plants Pittsburgh-Empire meters are used to measure the heated water circulated through digestion tanks, and all cold water piped through the plant for various uses. Hot water meters are made with heat-resisting working parts and registers to stand up under high temperatures.

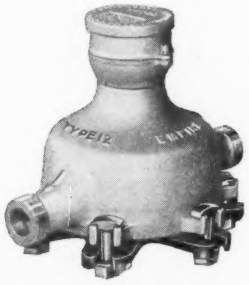

FIGURE 1.—Empire Oscillating Piston Water Meter.

These meters are made in disc, piston, current and compound models to suit every type of water measurement requirement.

Emco Sludge Gas Meters

The utilization of gas generated during sludge digestion presents the opportunity to effect marked savings over the cost of purchased fuel. This self-generated energy has a high b.t.u. value and can be used for central heating, water heating, to fuel incinerators, or as power for gas engines.

Accurate, dependable metering of sludge gas is necessary to prove its economies and control its use. Accepted engineering practice calls for the installation of meters to (1) measure the entire gas flow from each digestion chamber; (2) measure the gas used in water heaters, incinerators, boilers, heating furnaces, and gas engines; and (3) measure the gas wasted.

FIGURE 2.—Emco Meter for Sludge Gas.

Experience has shown that the conventional meter used for measuring manufactured or natural gas will not operate satisfactorily on sewage gas service due to the destructive effect of this gas on materials commonly employed in construction. For this reason Emco sludge gas meters are especially constructed from materials that have been laboratory and field proven to be resistant to the action of this vapor.

Outer cases are of heavy cast iron or pressed steel with interior surfaces protected by a special coating. A custom tannage and treatment is given to the diaphragms.

ROYER FOUNDRY & MACHINE CO.

176 Pringle St., Kingston, Pa.

Each of the postwar years has underscored an increasingly serious world problem, namely food! Everywhere population is increasing. But food supplies are not expanding at all!

One of the valid ways of increasing food supplies is by making soils more fertile. The vast volume of digested sludge and heat-dried activated sludge produced annually at sewage disposal plants is a source of soil fertility which has been used very little.

Sewage sludge, usually disposed of by burning or burying, is a fine fertilizer material. It is rich in humus and microorganisms that are essential to good growth of plants.

The fertilizing value of sewage sludge has been fairly well known for many years, but its widespread use has been retarded by the excessive labor and trouble of preparing sludge for market by ordinary methods.

Royer Sludge Disintegrators have overcome this difficulty for sewage disposal plants. The Royer machine accomplishes the entire task of fertilizer preparation very simply, with only one or two men shovelling sludge cake into the hopper. Furthermore, the cake does not need to be exceptionally dry. The Royer has successfully worked sludge with moisture contents up to 56 per cent.

Sludge from the hopper falls on an endless belt moving at a speed of 900 ft. per minute. Steel teeth on the belt

FIGURE 2.—Disintegrating caked sludge with Royer equipment at the Wisconsin Rapids, Wis., sewage works.

FIGURE 1.—Royer Sludge Disintegrator discharging sludge into truck at Charlotte, N. C., sewage works.

comb the mixture, break up the lumps, shred to pea size, and discharge the sludge out into a pile or truck as desired.

Figure 1 illustrates how easy it is to load usable sludge directly into a truck.

The Royer in action at the sewage plant at Wisconsin Rapids, Wis., Figure 2, shows how simply coarse sludge cake is transformed to a light, fluffy material.

Royers are made in a wide range of sizes and are powered by electric or gasoline motors, or may be belt driven from tractors. Get the facts. Write Royer for a free Sewage Sludge Catalog.

UNITED STATES PIPE AND FOUNDRY COMPANY

General Offices: Burlington, N. J.

CAST IRON PIPE FOR SEWERS

The use of cast iron pipe for sewers is steadily increasing throughout the country. Many new sewage treatment plants are being built, some in conjunction with new sewer systems and others to augment existing systems. Furthermore, major revisions are being made in large numbers of existing treatment plants, not only to increase their capacity but to provide more complete treatment that will produce an effluent of better quality. Treatment costs money; therefore, every gallon of water that seeps into the

FIGURE 1.—Installing 14-in. and 18-in. flexible joint cast iron pipe for dual line sewer siphon across the Passaic River, Fair Lawn, N. J.

mains through leaky joints, cracked pipe, or from other sources not only crowds the sewer but costs good money to convey it through the various treatment stages.

Cast iron pipe possesses three outstanding properties that are most important for present day sewer construction:

1. Tight pressure-type joints that prevent infiltration, thereby reducing treatment costs and, incidentally, eliminating trouble with tree roots.

2. Compressive strength to resist heavy earth loads due to deep fills over the pipe. Beam strength to withstand stresses caused by earth movement. Bursting strength to resist internal pressure when used as a force main or when pressure might occur temporarily due to floods.

3. Long life that has been proven by years of satisfactory service, consequently permitting a low amortization charge on the original investment.

VAPOR RECOVERY SYSTEMS COMPANY

P.O. Drawer 231, Compton, California

All sewage plants are now being equipped with operating gas control refinements comparable to the most highly specialized installations. The Vapor Recovery Systems Company, long experienced in gas control and safety equipment design, manufactures a complete line of this type of equipment.

At multiple digesters, "Varec" Approved Pressure Relief and Vacuum Breaker Valves with Flame Arresters are installed on the digesters and gas storage tanks to maintain operating pressure and for protection in case of fire. Constructed of aluminum, these units are non-corrosive in sewage gas and afford simple inspection and maintenance.

"Varec" Approved Flame Traps are installed wherever there is a possibility of fire inside the plant piping. They are also made of corrosion resisting aluminum and afford positive flame stop. All "Varec" Flame Arresters are listed by the Underwriters Laboratories for service more severe than that encountered in sewage plants.

To maintain system pressure at the waste gas burner, a "Varec" Pressure Relief and Flame Trap Assembly is installed. This unit consists of a sensitive reducing valve in conjunction with a "Varec" Flame Arrester into which a thermally operated by-pass valve is built. In case of fire in the system, this by-pass valve automatically closes the regulating valve and provides positive flame check.

"Varec" Approved Waste Gas Burners are made in wide capacity range and are furnished either with or without pedestal mounting. The pilot gas line is protected by a "Varec" Approved Flame Check.

To handle sudden surges in pressure, a "Varec" Approved Explosion Relief Valve is installed in the system. Dead weight loaded, it insures positive and foolproof relief.

Where the gas is used at boilers, engines, etc., a "Varec" Approved Pressure Regulating Valve is installed in the gas line to each piece of equipment. These valves operate at lower pressure than the "Varec" Pressure Relief and Flame Trap Unit, thus assuring that all gas required is available for useful work before any is allowed to go to waste.

"Varec" Approved Manometers are used for indicating system pressures. They are obtainable in single or triple

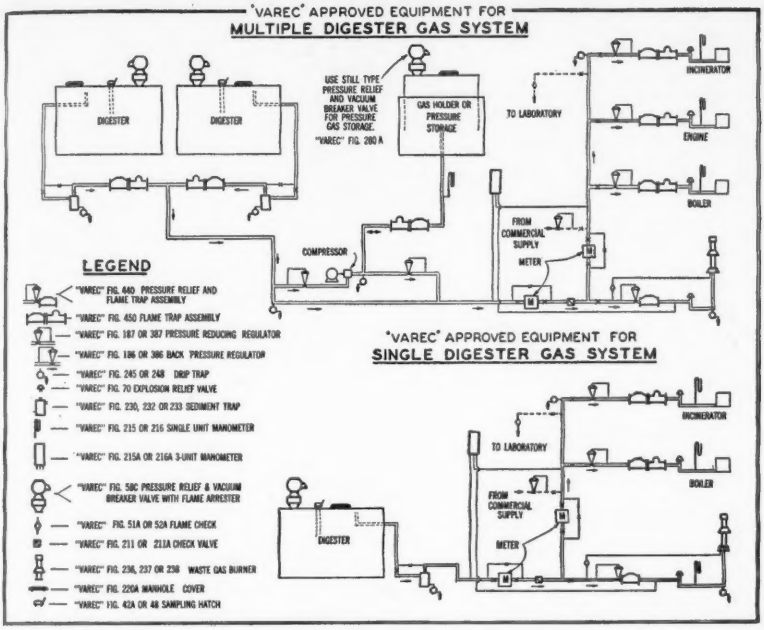
"VAREC" APPROVED EQUIPMENT FOR
MULTIPLE DIGESTER GAS SYSTEM
DIGESTER
DIGESTER
USE STILL TYPE PRESSURE RELIEF AND VACUUM BREAKER VALVE FOR PRESSURE GAS STORAGE "VAREC" FIG. 280 A
GAS HOLDER OR PRESSURE STORAGE
TO LABORATORY
INCINERATOR
ENGINE
BOILER
FROM COMMERCIAL SUPPLY
METER
COMPRESSOR
LEGEND
"VAREC" FIG. 440 PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 187 OR 387 PRESSURE REDUCING REGULATOR
"VAREC" FIG. 186 OR 386 BACK PRESSURE REGULATOR
"VAREC" FIG. 245 OR 248 DRIP TRAP
"VAREC" FIG. 70 EXPLOSION RELIEF VALVE
"VAREC" FIG. 230, 232 OR 233 SEDIMENT TRAP
"VAREC" FIG. 215 OR 216 SINGLE UNIT MANOMETER
"VAREC" FIG. 215A OR 216A 3-UNIT MANOMETER
"VAREC" FIG. 58C PRESSURE RELIEF & VACUUM BREAKER VALVE WITH FLAME ARRESTER
"VAREC" FIG. 51A OR 52A FLAME CHECK
"VAREC" FIG. 211 OR 211A CHECK VALVE
"VAREC" FIG. 236, 237 OR 238 WASTE GAS BURNER
"VAREC" FIG. 220A MANHOLE COVER
"VAREC" FIG. 42A OR 48 SAMPLING HATCH
"VAREC" APPROVED EQUIPMENT FOR
SINGLE DIGESTER GAS SYSTEM
INCINERATOR
TO LABORATORY
BOILER
FROM COMMERCIAL SUPPLY
METER
DIGESTER

FIGURE 1.—Gas flow diagrams illustrating applications of "Varec" Approved Equipment.

reading units with or without push button control, a feature that prevents gas escape if the manometer glass should break.

One basic design fundamental in gas plant engineering is to keep the lines free of moisture. "Varec" Approved Sediment Traps and Condensate Drip Traps are available to meet this requirement.

The "Varec" Approved Check Valve is required in a low-pressure system. A minimum pressure is required to open the aluminum clapper only in one direction.

"Varec" non-sparking and gas-tight manhole covers provide a quick entry into digesters. "Varec" Gauge and Sampling Hatches, also gas tight and non-sparking, have a foot pedal to facilitate sampling and gauging.

All "Varec" regulating and control equipment is flow tested in a modern laboratory. Design curves for each device can be used to determine the economical size for each specific job.

WALKER PROCESS EQUIPMENT INC.

Aurora, Illinois

Clogless Air Diffusion

Walker Process Equipment Inc. has developed a new nozzle for their Diffusair (Impingement Aeration) apparatus which will operate on raw sewage without requiring any recirculation line screening.

This nozzle is frusto-conical in shape, being slightly "hooked in" at the discharge end to cause a strong core ve-

locity tendency. The nozzle is further equipped with projecting non-clogging vanes to impart a twist to the stream and further intensify the core velocity, besides giving better diffusion at the impinger cup.

The inlet end of the nozzle is slightly larger than 1¼ in. and the discharge is slightly larger than 1 in., which gives a unit able to keep operating under all "tough" conditions.

This new nozzle is to be built from a ceramic material and will give better all-round performance than anything previously offered.

Grit Elevating

Walker Process Equipment Inc. has developed a new drag conveyor and elevator grit chamber design. This new design eliminates all tendency for flights to "bog down" because it does not bring back to one end more grit than is being washed and elevated. This design eliminates entirely the necessity of partial grit return or special agitating streams for grit-washing purposes.

The grit is dragged to one end by a rugged flight conveyor mechanism. At the end, the grit is dragged over a projecting ledge from whence it falls into the elevator hopper.

The elevator is a separate, independently operating mechanism which carries grit away (elevates to any desired height) much faster than the combined drag load of the conveyor can bring it in.

In this way the drag mechanism is kept free and never overloaded, and the transfer of grit from one mechanism to the other effectively washes under all flow conditions.

This new grit conveyor-washer-elevator is capable of collecting and elevating rolling-mill scale or cinders.

Each unit is furnished in capacities up to 2 cu. yd. per hour.

WALLACE & TIERNAN CO., INC.

Newark 1, New Jersey

Sewage chlorination, once considered a "luxury" item in sewage treatment, has in the last few years made such advances and has proved itself such a versatile tool of the sewage works operator that it is now generally recognized as an indispensable part of a modern sewage treatment plant.

In general, sewage chlorination can be divided, by purpose, into three major categories. First, there is what might be called "esthetic chlorination" including chlorination for odor control. Second, there is "process chlorination," employed in various ways, such as to control sludge bulking, to aid in the treatment process and make satisfactory sewage disposal easier and more economical. Third, there is what is rapidly getting to be "required chlorination" in the form of effluent sterilization to reduce stream pollution.

Aside from increasingly stringent pollution abatement regulations, however, effluent chlorination is almost mandatory if a community is to preserve for itself and its visitors attractive bathing beaches, fishing and camping spots, and other recreation areas. In a sense the same principle applies as well to the other types of chlorination.

Considered from the standpoint of location—or point of application—many of the specific benefits of sewage chlorination may be shown. For example:

Interceptor Chlorination is employed to control odors, prevent septic-

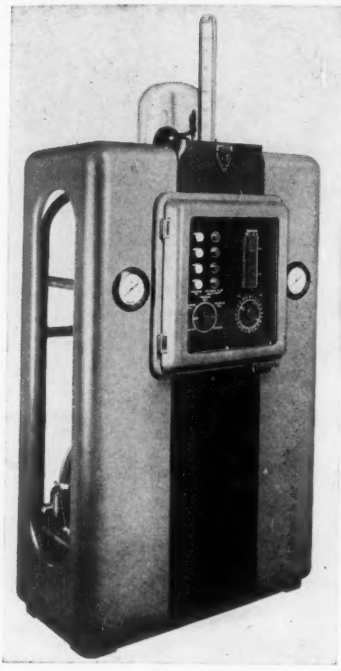

FIGURE 1.—W & T Program-Controlled Sewage Chlorinator.

ity and reduce hydrogen sulfide damage to concrete structures.

Plant Chlorination serves many purposes including odor control, elimination of hydrogen sulfide corrosion, prevention of filter ponding and sludge bulking, improved settling and digester supernatant treatment.

Effluent Chlorination gives B.O.D. reduction—particularly important to plants discharging into watercourses having seasonal flow variation, protects downstream water intakes and keeps bathing and fishing areas in shape as healthful, pleasant recreational attractions.

To meet the various requirements of sewage chlorination, W&T has a full line of chlorination equipment ranging from Hypochlorinators to high capacity Visible Vacuum Chlorinators. Controls on most types can be supplied for manual, automatic start and stop, or full automatic proportional flow operation. The newest W&T Sewage Chlorinator, Figure 1, is a program controlled unit, designed especially to meet the unusual conditions encountered in sewage chlorination.

For detailed recommendations on *your* sewage chlorination problems without obligation, just communicate with any W&T representative or with Wallace & Tiernan, Newark 1, N. J.

YEOMANS BROTHERS COMPANY

1411 North Dayton Street, Chicago 22, Illinois

SEWAGE TREATMENT EQUIPMENT, SEWAGE PUMPS, PNEUMATIC SEWAGE EJECTORS, ROTARY AIR COMPRESSORS, VACUUM PUMPS

"Package Aerifier" Plants

Yeomans' "Package Aerifier" plant has enjoyed continued popularity in solving sewage treatment problems of small communities, institutions, schools and subdivisions. The many unique features of this "made to order" plant present an efficient, low cost, odor and trouble free complete sewage treatment plant for communities up to 3,500 population. They are simply operated and present a pleasing appearance (Figure 1). A refinement of the mechanical details offers efficient screening and sludge handling through the Type SS screening and sludge ejector, sludge and scum collection with the "Streamline" sludge col-

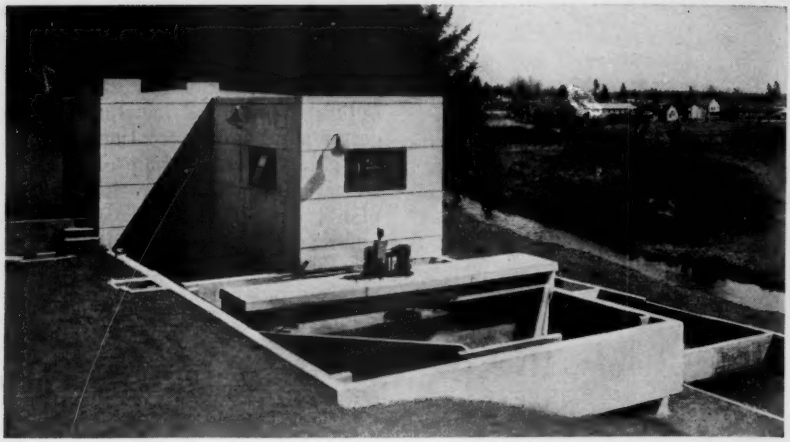

FIGURE 1.—Yeomans' "Package Aerifier" sewage treatment plant, Parkland, Wash.

lector, and complete aeration with the "Spiralflo" mechanical aerator. The economy of the combination aerator and final clarifier in one concrete structure has long been demonstrated and the low cost of operation is a source of great satisfaction to engineers and owners alike.

The Aerifier was developed specifically for handling the wastes from small communities with a view toward reducing, as far as possible, the amount of mechanical equipment and operational attendance necessary.

High Capacity Aero-Filter

Records from Aero-Filter plants in operation continue to prove the many claims made for this type of high capacity filtration. The obvious saving in construction cost over the conventional type filter has proven a boon to municipalities faced with the construction of sewage treatment facilities during these days of high construction costs. The gratifying low operating cost, due to the fact that no recirculation is necessary for the purpose of diluting the sewage applied to the filter, has received very favorable comment from all parties concerned.

Recent development in the arrangement of the distributor arms has improved the distribution of the applied sewage to the point where even the smallest beds, using reaction type distributors, get complete momentary coverage with the rain-drop spray required by the Halvorson-Smith process.

In the past year, a decided interest has been manifested by industrial organizations for the use of the Aero-Filter in the treatment of all types of trade wastes. The Aero-Filter is unusually adaptable to the treatment of strong industrial sewage, and plants have been designed for all types of canning plants, packing houses and breweries.

The Aero-Filter System has been used in numerous cases in the rehabilitation of heavily overloaded conventional trickling filter plants.